

URL: [https://ecorner.stanford.edu/?post\\_type=video&p=56186](https://ecorner.stanford.edu/?post_type=video&p=56186)

The tale of 3D Robotics starts in the garage of a teenager in Tijuana, Mexico, who launched a drone-making factory with a \$500 check from entrepreneur Chris Anderson, who then flooded the American market with their unmanned aerial vehicles and disrupted the aerospace industry through grassroots, open innovation. Then, China caught on and drove U.S. drone makers into the ground. Anderson, 3DR's CEO, shares his hard-won insights.



## Transcript

- First, I'm gonna start with a quick show of hands.. How many people saw the Falcon Heavy launch yesterday? Okay, so this is not that story.. (laughter) But, this is on the continuum of that story.. So we now measure entrepreneurship by Musks.. (laughter) So I would say, this about a two millimusk story, but it's not a zero millimusk story.. And I hope you can see glimmers of the courage, and ambition, and techniques that Musk used in SpaceX, in what we did with drones.. Not just because they're both in the air.. So, I'm gonna start by, I mean basically over the course of this I'm gonna tell you sort of my story, you know, make it as narrative as possible, but I'm also gonna be telling two stories.. One is about the use of open innovation as a disruptive tool and then ultimately a business founder.. And the other is going to be a sobering, but I hope also inspiring story about what it means to compete with great Chinese companies..

And without ruining the surprise We lost.. (laughs) But maybe we also won.. So I'm gonna start with the year is the year is 2007.. And I'll show you some pictures of my kids in a moment.. But basically, think about the aerospace industry as looking like any other industry which is to say that it was a very mature industry, it had lots of big companies, Boeing, Lockheed, McDonnell Douglas et cetera.. It's pretty well populated around a slide that you've seen many, many times, which is that there's price and there's features and the more features the higher price, et cetera.. And you should assume that this is, that this is sort of fully populated.. And then you might ask yourself, why would anyone want to enter the aerospace industry? In our case the air, in Musk's case, the space.. And the answer is that there's no units on this chart.. And if you put units on this chart you suddenly realize that it starts at expensive and goes to very expensive..

Now the second book, as Matt mentioned I wrote in the, sort of the long tail trilogy, was free.. It was a book about the use of zero marginal cost economics to, i.e the internet digital distribution as a form of marketing and changing a business model, to a freemium business model.. But the point is is that, as everyone has learned in economics, there is the notion of price elasticity, in that if you lower the price, you should discover demand, markets, customers that you might not have also previously found.. Now, the reason why the aerospace industry sort of started at expensive and went to very expensive is because they were assuming there was essentially one customer, at least in space.. And also true for drones which is the business I was in, and that is the government.. The government is a, sometimes it's military, sometimes it's NASA, et cetera, but it's the government.. And there is a certain amount of regulation that comes with this, procurement processes and all this kind of stuff.. And basically, it's very You know if you ask Elon Musk, which I did, I said, "Elon, Mr.. PayPal, Mr.. Tesla, "Mr..

SolarCity, what makes you think that you can go to Mars?" He didn't say material science, he didn't say Moore's law, he didn't say software, he said cost plus accounting.. Cost plus accounting means that the economic model of the aerospace is broken, the economic model of aerospace is that the government says, what's it gonna cost to make this, and you say X, and they said we'll give you X plus, cost plus.. So there's no incentive to lower X because the government will give you a profit on whatever you say X is, if you win the contract.. Anyway, Musk said this is a completely flawed economic model it doesn't incentivize lower cost and if you lower the cost you can discover markets that maybe are beyond the government, maybe there's a whole bunch of people who would love to put things in space but they can't afford to do it and if you lower the cost by say 10X, maybe you'll find more than 10X as much demand.. So, I don't do space but I did do something else.. I did drones.. Now, I didn't actually do drones as you'll see, I did Lego with my children but we'll get to that in a moment.. But the point is, is that I am a, I am not an aerospace guy, I am not a, I wasn't even a hardware guy but it was pretty clear that something in

the world had changed to lower the barrier to entry to kind of basic kind of computers, sensors, autonomy and things like that.. And I sort of did this experiment, I said what if you, what if you took the essence of a drone which is an autopilot, and you basically said that's a computer with software and what if you said, well, computers with software these days cost about 10 cents, what if we just sort of put a computer with software on a little board and call it.. and charged \$19 and said you could put it in any kind of toy plane, it would be a drone..

What would that be like? And the answer is that it was ridiculous, it was, it barely worked, it was hard to use, it was dismissed as a toy, and people rightly laughed and said that's not a Predator, that's not a Global Hawk, that's not a drone, that's just an Arduino and a foam plane.. And I said okay, that's cool, what if you made it a little bit better and charged \$30? Anyway, eventually we made autopilots for about \$90 and we, by the time they stopped laughing we'd put two million drones in the air.. We'd put more drones in the air every week than all of the aerospace companies in the world combined.. And now, at a certain point they said, "Well, I guess maybe those are drones, "we hadn't really thought of them that way." And so we just said, "Okay we'll just put them in this." Here, this is one of them.. We said, "Well, okay, if you don't like the autopilots, "we'll just put it in a vehicle that flies." And they're like, "Oh, I guess that is kind of a drone," and I'm like, and we're gonna find useful things to do with it, and this is what my company does today, is we just use drones to scan the world.. And now we're doing like what satellites do and reality capture and laser scanners etc.. and we're just, we're now we're like part of the construction industry, and no one, it didn't occur to anybody back in those days that drones would be useful for that, they thought it was a weapon.. And the notion that it could be a way to monitor construction sites or insurance or wildlife was just not possible.. But this is what happened and by the time we started doing this, it got the price from \$10 to \$20 up to about \$10,000.. The aerospace industry woke up and said, "I guess we need to lower the price," and they did their damndest and they managed to lower it to about \$100,000..

So this model is exactly what's happening in aerospace as well, that the incumbents who spent their entire life as companies setting up procurement processes and ensuring that the regulatory barriers were such that nobody else could come in, suddenly are confronting somebody who came from outside with something that initially looked like a toy but had accomplished the job through different means.. So that's the kind of the economic over picture, now how did it actually happen? And the answer is it was in fact Lego, that's my nine-year-old daughter, Erin.. At the time I was the editor of Wired, I have five kids, my wife and I are scientists by training and our kids are not interested in science.. We think that's a problem and we keep trying to change that.. And so one day at Wired, we got these products in for review.. Lego sent the new Lego NXT robotics kit and somebody sent a radio-controlled airplane and I thought that's gonna be awesome.. We'll make robots on Saturday, we'll fly a plane on Sunday, something will stick, and so this is Erin reading the instructions, this is her brother Daniel, hoping it'll work, The good news is it worked, the bad news is that it was completely unimpressive to a kid.. If you have seen Transformers, this doesn't do it.. They're like, "Where's the frickin lasers? "Why doesn't it walk?" Real robotics is incredibly disappointing compared to computer graphics.. So, that sucked, and then we flew a plane and I flew it into a tree and that sucked..

And so I said, "Well, how could that have gone better? "How could I've had a cooler robot "and a better flying plane?" and I was like, "What if the robot flew the plane?" Well, and so I googled flying robot.. And if you google flying robot, the result is drone.. I'm like, "Oh yeah, I guess that's what a drone is, "it's a flying robot." Wait, what's a drone? You google drone and it'd say aircraft with an autopilot.. I'm like, "Oh yeah, play with the brain, I get it." Wait, what's an autopilot? If you google autopilot, it just turns out that it's sensors and computing software and it basically has to sort of figure out where down is, then has to figure out where it is and then has to kind of follow a path.. I'm like oh, that kinda sounds like what's in the Lego Mindstorms kit.. It's computer and sensors and software, so let's just do it.. So here it is, the world's first Lego autopilot, these are gyroscopes, accelerometers, magnetometers, Namco processors, stuck a GPS on it via Bluetooth, stuck it in an airplane and it flew.. Badly.. But that airplane is actually now in the Lego Museum in Denmark as the world's first Lego unmanned aerial vehicle, UAV.. It turns out that drones and auto pilots are regulated as cruise missile controllers, and they're export controlled, and that the act of putting this on the internet was a violation of Export Control..

We weaponized Lego, which is one of my proudest moments.. So, at this point my kids lost interest and went back to video games and I'm like wow, what just happened? Around the dinner table, my kids and I made a drone out of Lego and like balsa wood, something in this world has changed, what? So I created a website called DIY drones, and there's a lot to be said for putting the letters DIY in front of traditional industries, it really expands the mind.. And so what happened is that just like a ton of people were thinking about the same thing at the same time as part of the Maker Movement, and it took off.. And this community came together and they started working on the software and working on the electronics, and doing what open-source communities do in a very kind of informal way.. And at a certain point, it became clear we had a thing.. As a matter of fact, we had the biggest robotic community in the world, accidentally.. Remember, this is a hobby, I'm doing part time and in weekends, and it's starting to kind of reverse engineer the military industrial complex as a hobby, which was not our intention and yet it kind of happened.. It wanted to happen.. And so at that point, everyone's like, this is awesome, code, code, code, print the circuit boards, solder, solder, solder and then a bunch of people come along and they've heard about drones and they're like, "I totally want to do this." And we're like, "Here, here's the code, just compile that "and populate your PCB, fab your PCB, "and populate your PCB over here," and then they're like, "What, do you just have like a kit or something "that you could sell?" We can do that, so here it is, our first production line.. Those are yes, my children..

These parts are Lego parts, the cool part was that when I wanted the motors fabricated, this actually is for a robotic blimp,

but when I wanted motors fabricated, I'm like I know nothing about motors.. And I said I'll bet they're made in China and I went to Alibaba, and I went to order motors.. Because one of the important economic lessons you learn when you're selling things is that you can't buy things at retail price if you intend to sell at retail price.. You have to buy it wholesale to sell retail, so I didn't know where to buy whole motors wholesale.. So I went to Alibaba, and I found a company that manufactured motors and I said, "I would like to buy some motors." And they're like, what kind would you like to buy? And I'm like what do you got, and they're like what do you want, and I'm like what do you got and they're like, here, here's a little sort of widget by which you can pick all the elements, the windings, the shaft size, the magnets, etc.. And then just when you're ready, just pick the quantity.. And I'm like, "I can design my own motor?" They're like yeah, and it's all real-time translating between Chinese and English, and I'm like designed it.. And then they're like okay, terrific, I got to the end and now here's a price per motor, and I'd wanted like a hundred.. And it turned out the price per motor for a hundred was like three bucks each but for like ten thousand, they were like 60 cents each.. No, they were less than that, like 35 cents each and I'm like I don't need 60,000 motors, but how can I resist, so I just picked that..

10 days later, this box comes and all of my custom design motors had just been shipped from China.. And it took PayPal.. I was like I just got robots in China to work for me, designing a custom motor and they took PayPal.. This is, something in this world has changed.. I paid the children in strawberries and juice.. We made this.. So the good news was that it sold out immediately, the robotic blimp kit.. They had an autopilot but it was obviously an easier one designed to sell at Maker fairs.. Then we learned another important lesson about economics.. So I went to the kids and I said, "Good news, the blimps are hip, they sold out immediately." And they're like yeah, whatever and I'm like, "You know what that means?" And they're like, no, it means we got to make more..

And they're like, "No way, that's not gonna happen." And I'm like okay, that's a problem, I'm not gonna make more, my kids won't make more, what am I gonna do? So I found this guy in our community, one of the first guys who was there and I'm like his CV seems super smart.. His name is Jordy Munos, and he was flying a helicopter with a Wii controller, that was awesome.. I was like, "Jordy, you seem super smart.. "You seem to know everything, "do you want to help me out here?" He's like, "Yeah." He said, "I got a little spare time." (mumbles) And he says, yeah, I'll solder together some some boards for you and I'm like cool, what do you need? And he said, "I need some parts though." "How much?" "About 500 bucks," so I sent him a check for 500 bucks.. And he sends me back this picture and there he is soldering the board.. So I'm like, done, okay, hobby now fully off in the hands of Jordy, 500 bucks, maybe it was a lot of money but I'm sure it will work out okay.. And, he sends me back another picture and he says, "I hired some people, it's selling really well.. "We're now selling other auto pilots and there's sensors "and things like that," and I'm like, he said we've got a little industrial space.. I'm like that's incredible, they got shelves.. He has a book keeper, it's really good..

In the back they have a reflow oven for printed circuit boards, it was a toaster oven from Target that was repurposed.. I'm like, who knew he was such a pro.. He sends me another picture and he says, "Yeah, so we scaled up." These are pick-and-place machines and reflow ovens and stencil and printers and CNC is in the back and now about 30 people.. We're on track to do about \$5 million this year.. Remember, I've sent him a check for \$500, I have not met him yet.. And I'm like okay, I think I need to go down and meet him.. So I met him and it turned out that, when I'd first contacted him, he was a teenager in Tijuana and he had dropped out of college and, he and his wife were just moving to the US so that his child would be born and become a citizen so he had some spare time waiting for his green card.. And so this was like a perfect fit for him and then he said, "Oh, by the way, "we've opened up a second factory in Tijuana, "and here it is." And now they're wearing smocks with our logo, which I think I'd drawn in Microsoft Paint or something.. And the thing, you can't see it on this picture but what I love about this picture is that, is that the, at this point he's really pro and he's got electrostatic discharge protections.. So there's these cables that connects you to the machines that the static electricity has dissipated..

And my friends who, like me don't know anything about electronics manufacturing are like, "You chain your workers to the machine? (laughter) "So cruel." And then at this point, we're now the biggest drone manufacturer in America.. This is like the second plant in Tijuana.. By the way, I think the Tijuana drone factory is a great name for a band, it's not taken yet.. Totally good for that.. So I'm like I think I need to quit my job.. I think we've accidentally created a different form of aerospace company, so we raised some money, I quit my job, moved the headquarters to Berkeley where I'd gone to school, where I lived.. And off we went.. So, when I say we disrupted the aerospace industry, this is what we did.. This is where we launched, right there.. This is the price of helicopters, import price of helicopters in the United States..

We basically destroyed the helicopter industry, because it turned out, not because we make helicopters, but because we made another way to levitate sensors in the sky.. It turns out a lot of helicopters didn't want to be helicopters, they didn't want to have pilots.. They just wanted to put a camera in the sky, like traffic helicopters or firefighting helicopters or lidar scanning, they just want to put a sensor in the sky and there's better ways to do it than putting a man in the sky, a human in the sky.. So, you don't see that very often.. Remember, this is me, I'm right here at the dining room table with my children and Lego, right? This is me right there sending \$500 to a teenager in Tijuana this is the teenager in Tijuana building a factory on his own with like, by buying used pick-and-place machines on eBay and downloading the manual from the Internet.. And this is the US helicopter market.. Now, we didn't do it alone, I have to say, that this point a lot of other people, where starting to use our autopilot and we created an industry of people who are this kind of bottoms-up grassroots approach to aerospace.. But that's pretty profound.. Unfortunately, because of the scale you can't see it, it starts at \$1 million and it pretty much looks like it goes to zero.. It didn't go to zero, it went to about \$1,500 which is where we came out with this..

But that same force that we used to disrupt the aerospace industry was used to disrupt us.. And a very good company, named DJI out of Shenzhen just did what we did but did it better.. They brought the cost down, they brought the innovation pace up and the price of consumer drone went from \$1,300 to \$500 in nine months, which I don't think the world has ever seen either.. And that is, that's the neutron bomb, right? That is the end of the American drone industry, or at least consumer drone industry, that's it, boom.. It's gone, everyone is gone, we're gone, GoPro is gone, Lilly, and everybody.. It completely vaporized the American drone industry on the hardware side.. So I'll talk about that in a moment.. So this is pretty dramatic, right? I mean this is like, we talk about disruption, this is the future of aerospace that's being played out at like, lightspeed on a global scale using open innovation, using all sorts of ways to get around regulatory barriers without breaking the law.. Things like Export Control, and FAA regs, all of them exemptions for what we were doing.. So that's pretty dramatic..

And so, basically, this is, when you pull back, this is what happened.. There was an industry that was going like this, and it was gonna continue going like that forever until suddenly we came out of nowhere, and we're like, "Hey, it's just developer stuff, it's just boards, "it's just autopilots, it's just open source code," and they laughed, right? And now we're like, "Hey, you know what, "you can actually put that in some plastic "and batteries and motors," and it's a pretty cool, it actually works, it's really easy to use.. And maybe the audience again, discovering new audience, maybe the audience is not the Air Force or the CIA, maybe the audience is like kids at Christmas, or maybe the audience is like construction workers or maybe the audience is like scientists looking at land management.. So we've made it really cheap, maybe you'd find something there if you'd only made it easy for them.. And then we went a little further and they're like, you know what, maybe, maybe this isn't even about drones.. Maybe this is just about measuring the world, maybe this is more like satellites and the internet of things than it is like aerospace, maybe we're just extending the Internet into the sky and that becomes a kind of really big deal.. So this is what's happening, we're right about here right now which is to say the consumer one is still bigger but the enterprise side of drones are becoming a thing.. And so when you look at how we did this, we basically disrupted an industry by doing, everything they did we did the opposite.. And this is pretty much, it's not Elon Musk exactly but it's pretty close.. So rather than high price, we're like, how about zero or as close to zero as we can get, rather than the aerospace industry which has an impeccable record of safety..

It has never been safer to fly a, you can fly in a jetliner today, we're like, "How about if we crash all the time in the beginning, "because we're learning?" But don't worry, no one's on board so nobody gets hurt.. And so it's like, so the aerospace industry is like, even the notion of nines, five nines, six nines of reliability, we like spent three years going for one nine.. Because before, initially, it would like crash every time we flew it.. And then by the time we were at about 2010 or so, it crashed about once every 10 times which was pretty good, that's one nine.. Then it crashed about once every 100 times and that was pretty much where we were ready to go to consumer side, 'cause remember your phone probably crashes one out of hundred times use.. And now we're shooting for about three nines, crashes about one out of 1000 times but it's no big deal, nobody gets hurt, they're cheap.. And that's the thing is, if you take nines out of the equation then the pace of innovation really accelerates.. And if you don't have humans on board, then the risk of innovation, the cost of crashing is so low that you don't have to emulate the aerospace model.. The aerospace industry is highly regulated.. It's Export Control, it's FAA, its FCC, it's Department of Transportation, the works and we're like let's not do that, let's not replicate the aerospace model, let's find ways where we can find sandboxes where we can innovate that have no regulations..

And so we found under 400 feet, within visual line of sight no flight over people, no flight at night, suddenly it's deregulated.. You don't have to get these permissions.. We said initially, if you sell to consumers you have to get FCC approval, if you sell to developers, you don't.. You have Export Control unless it's public domain, open-source public domain, at least so we argued exempted from export control.. And everyone's like, these rules were written in the 70s, it never occurred to them that cruise missile controllers were going to be created by nine-year-olds on dining room tables with Lego.. And so, the notion of public domain, cruise missile controllers which is essentially what an autopilot is, this wasn't a thing.. It never occurred to them that this could happen, and yet it did.. So we just found ways where the regulations were low, the pace of innovation as a result was high and the numbers of customers was super high.. Again, millions of drones in the air while the military industrial complex was putting hundreds of drones in the air.. So, this is what happened..

We started with these with these worlds, we sort of said, "Hey, there's these guys who are interested," people were interested in robots and that was kind of me and then there were a bunch of people who were interested in radio controlled airplanes.. And we said, what if we put the robot in the airplane and that's the thing you saw with that yellow plane with the Lego in it.. And that was kind of interesting, so we merged two communities and that was DIY Drones.. And then we said, okay, well that's pretty cool and then a bunch of people said, "Hey, can I just buy it?" And that's created 3D Robotics, now known as 3DR which was just designed to commercialize the work of the community.. And then the RC people who really like flying didn't want auto pilots, and they were like, "I just wanna, I like sticks, "I mean I want the joy of flying." We're like great, that's not, that's not for us.. But still that could benefit from autopilots to make it easier to fly.. So the toys are manually piloted, taking videos of things, manually piloted and drone racing is manually piloted and that was good fun but that's not the direction we were going.. Then we were saying we want autonomy, we want to make these truly pilotless vehicles, so we're gonna focus on the software and the hardware side and that's 3DR and that created the solo.. And then we got our, and then the video guys who like flying, they actually tried to start commercializing what they did and so some of them became pilots who did drone services as a service, drone as a service.. And that's great, that's not what we do..

We on the other hand decided to get out of the hardware business 'cause DJI was amazing and we just focused on the

software, and then there's the drone software that flies in the drone, and then there's the software to analyze the data.. And we did the data side which is called site scan and that's using data to scan construction sites, and we spun off the software into the Linux Foundation as an open source community called Drone Code.. And today that's Intel and Qualcomm and ARM and Insitu and Flare and Unique and a bunch of others.. It's about 30 companies, and today, this is sort of the Android of drones.. And it's all open-source, and it is a consortium and it is run under an open governance model and I'm the chairman, but that's So this is the company, and this is the community and then there's a second community which I'm gonna talk about in a second called RG Pilot, which is sort of a standalone and one sort of all focused on business and then one's more focused on sort of developer friendliness.. And if this was a really sad thing, what happened between this, the splitting of the community into two forks, I'm gonna take a second to talk about this because it's a really important lesson on open innovation.. Don't do what I did.. This was, when you're doing open source, it's really important to structure the open source project both in terms of its governance structure and its license in a way that can be commercialized, if that's what you ultimately aim to do.. So normally, when you look at the continuum of open innovation, it starts with things like app stores, APIs, SDKs, etc.. And as you go into actual open source software, there's a bunch of licenses and there is a general sense that the more, the more sort of copyleft, the more radical the license the better it is, and the GPLv3 is the most radical of the licenses..

In 2009, when we were setting up the license, we had these community members who are amazing developers just the best I've seen but they were open sources zealots, and I'm an open source zealot or so I thought, and they were like GPLv3 is the most viral, it will get the most developer engagement.. People are required when they use this to give back, and I'm like that sounds good, that definitely spurs developer engagement.. I hadn't thought about what else that might mean but it turns out that the GPLv3 and this is super controversial, I'm gonna get shot for this metaphorically.. The GPLv3 is I think, was a crisis in the open-source community, it has essentially been banned by all big companies here.. It is, I would go as far as to say it's toxic for business.. I think it is fantastic for developers, but because of its viral nature, because everything, every time you change the software you must publish it.. It discourages companies from using it because it can infect everything else with this, this is forced to expose your IP, and as a result, nobody will touch it anymore.. Now this is not to be confused with the GPLv2 which is what Linux is.. The GPLv3 was a quite extreme deviation of it, and I think that fissure in the open-source software community is gonna be felt for years.. And I made the wrong bet..

I went GPLv3 with RG Pilot, and as a result, once we decided to commercialize it, no one would touch it.. So, we fortunately had another group called PX4 based out of the ETH in Zurich, another University.. And they had chosen the BSD license.. And so this one here is copyleft, and this one's permissive, the BSD license.. The BSD license is also completely open-source but you don't have to distribute if you make modifications.. You can choose to but you don't have to, and the BSD, the permissive licenses are the ones that companies embrace.. And so we had to divorce.. And so, one community went off GPL and they're doing great, fantastic software, fantastic community but really hard to commercialize.. And then we created a new, a competing stack on the BSD license, and that's the one that's now gonna be used by most companies including air taxis.. And for example the new Udacity air taxi course is based on this stack, the Drone Code stack which is a BSD license..

So that was super painful, I had to be a complete jerk and essentially fire the community I started because I made a mistake on the license.. And I don't feel good about it but it had to be done and I think that was something that we've learned a lot about over the last few years, about the differences between those licenses.. Okay, so, I've got, I'm gonna go like another 10 minutes here then we're gonna take questions.. So that was my story, that's that's what happened.. This is part of a, kind of a big, I've learned some bigger lessons about innovation and openness but basically, if you pull back, this is an experiment in the nature of the firm.. And you've probably seen these guys before, this is Ronald Coase, the sort of whose theory of the firm created this notion of transaction costs and that companies exist to minimize transaction costs and Bill Joy from Sun Microsystems who challenged that by saying whoever you are, the smartest people in the world don't work for you.. So Ronald Coase says, the only way to get things done is if people work for you and Bill Joy says well, that may be true but the smartest people don't work for you, John.. So, two, with terrible graphics and I know these are not the worst graphics that have done on this in this room but they're probably close, this is what Co said.. Co said hey transaction costs are very high until you create a company roles and responsibilities under one roof easy to communicate everyone has, knows what they do and the transaction costs drop as the company as the company gets more bigger and more professional and as you know that's not true it's true to a point but there's certain point companies get big and bureaucratic and then the transaction costs rise again so that's kind of a problem right you know we just seen GE one of the best companies in the world you know hit a you know the you know this is GE who sort of through great management manage to keep themselves here but you know but they were competing with companies that were down, that were down here and so even GE found that the the disadvantages of being big and bureaucratic outweighed the advantages so what do you do about that and the answer is as we I think we are collectively learning is that companies are a fantastic way to get things done up to a point and that the only way to get things done you know at scale that continues to be efficient like a little company is to merge a company with a community so 3DR was here and Drone Code is there and that is and that merger and that notion and by the way this is you know it's Stanford right this is Silicon Valley, we understand that communities are a big deal we understand that having open APIs and developer you know tools is the right way to do it, we understand the platforms are more important than products we get that but this is still a pretty radical notion out there in the world and how to do it well is not obvious so I think this is, if I were to get you know Coase and Joy into a room, I'll bet I think Coase is actually dead at this point, is he? Okay okay so it wouldn't be that fun a conversation but at some point you know imagining it that's where they would probably agree is that is that they're both right there just right at different scales so to summarize paradox, that's right to a point, that's the way it really works

and that's how you merge the two the two theories so my next, so you know Nobel Prize please.. Okay we talked about SpaceX I start on SpaceX here's just a little data, SpaceX is, so we were competing with the Lockheed's and the Boeings etc..

the aerospace industry.. SpaceX is competing with something called the United Launch Alliance which is a consortium of big aerospace companies and I just wanted to show you the numbers this by the way is maybe it's a few months out of date but basically the cost, so Falcon Heavy has one quarter the cost of the United Launch Alliance lifter one quarter the cost and twice the payload so basically it's eight X better pound per dollar ratio so call it order of magnitude and interestingly that's very common for for SpaceX is almost always about the order of magnitude factor of 10 cheaper than it's alternatives and that's something he's worked and what's interesting is that there's price elasticity in the in just in the, in there so this is the number of launches so in 2017 SpaceX did something like 12 is probably about 14 launches and the United Launch Alliance did eight launches so this is this is an example of him using price to discover new markets now he's first, this is gonna be micro sats and it's gonna be telecoms and it's going to be roadsters to Mars and who knows, but basically lowering the cost of access to space by an order of magnitude is a really big deal and we're and you're doing this with not just eliminating price, not just eliminating costs plus accounting but also eliminating the notion of disposable boosters and all the rest so you're seeing it playing out there you're gonna see it playing out in cars so I told you that 10 years ago I started a community called DIY Drones to kind of you know bottoms-up transform the drone industry well done it again now it's DIY Robo Cars and we're going to and we're now one of the biggest autonomous car communities in the world something on the order of four thousand participants who are racing almost every week, wheel to wheel but we're not doing it with full-sized cars and people on board in the road because I don't have a car and my, I don't want to die and I don't have permission to drive on the road.. So we do it at subscale, from go-karts on down I'm here I might go back how.. Actually so actually I'll just go this is what this is what it looks like we just added these warehouses, we put, we have hackathons every week.. We, this is Carl Bass the CEO of Autodesk who we turned into a crash-test dummy the steering wheel is disabled all he has is a red button that's a kill switch and this is and and it looks like a toy, sound familiar? that's a couple billion dollars of R&D, but they're kind of on the same continuum, we use the same technology we use the cameras we use tensorflow we use OpenCV, we use the cloud we use, the cost of this is about \$200, the cost of this is well you can't buy one.. Raspberry pi's versus a bunch of Nvidia boards.. Maybe a radar maybe a 2d lidar etc, but it turns out you can kinda emulate a lot of what's going on in the autonomous in the full-size autonomous car space for left for 200 bucks in a warehouse with a bunch of nerds and this is our data this is, we're doing pretty well.. We've got a neural network team these are, this is just the latest races the neural network teams have been getting, those are the the blue dots and the traditional computer vision is to think of this is like a proxy war with the neural network teams being like Google Waymo and the and the computer vision ones being like Tesla and so the Google Tesla you know proxy war is playing out pretty well.. I would say that in this I think actually I have updated for the next one I think the computer vision team has just pulled ahead maybe it means Tesla's going to pull ahead but what's interesting is that we're gonna beat humans by probably about August.. It's a bunch of a bunch of nerds in a warehouse in Oakland and 40 other warehouses around the world using open source software and raspberry PI's are gonna be faster than humans at scale, it's 16 scale up to go-carts by the end of this year..

Why do we do this? Oh, 'cause it's fun, 'cause we can.. What's the point of reinventing a wheel that Google and Tesla are already inventing and the answer is I'm gonna go right back to the same thing we did with drones we're gonna do things they don't do, first of all we crash all the time and that's good because that means we iterate really really fast and nobody gets hurt, second of all we race wheel to wheel that's not actually happening anywhere else in the world, no autonomous cars are racing wheel to wheel, we do it every weekend.. When you race wheel to wheel and we know this in the car industry this is how cars innovate, is that the car companies, the Ferraris and the Porsches etc.. they race wheel to wheel in Formula One etc and this is how automotive technology has always advanced except for in autonomous cars where we don't do that how about doing that, why would you do that? Well it turns out if you want to be safe and this is for those of you, I think a lot of you have engineering backgrounds, for those of you with an engineering background who understand control theory there's basically two ways to be safe, one is to be very very gradual, very slow, very cautious and the other is to be very nimble, very fast very highly responsive.. So, you can you can drive a little old lady and that's the way all autonomous cars are, autonomous cars are the first, the second order effect of autonomous cars is gonna be traffic jams everywhere because they're so conservative, if they don't know what do they stop and we're like well what if you just are super fast and you can nimbly dodge through traffic, I don't know, maybe that's a terrible idea but that's what we're doing.. I'll get other slides but I think on that note I'm gonna, oh yeah I wrote a book about all this stuff that you can read, but on that note of destroying, a bunch of amateurs getting faster than humans by the end of the year I think I will stop and take questions thanks very much.. (audience applause) I realized by the way I didn't, dig deep enough into the whole competing with China thing so some of the questions are about China that would be welcome.. Questions.. - [Woman] How do you compete with China? (laughter) - A plan, how do I compete with China um so the question was how do I compete with China, I described earlier on how DJI, it just just crushed all the American companies, basically all the companies around the world by being really good at what they do.. so DJI is a company that grew up in the Pearl River Delta and Shenzhen, I described the companies of that era as the ones that were making iPhones for 10 years and taking notes they basically, the iPhone processes and everything about Apple and the iPhone was something they were really well schooled on..

DJI, so, I lived in China for four years, my children were born there, and I knew that they were, that they were not, they were not just copying, they weren't just a low-cost manufacturer, I knew that there was a really strong engineering culture there and so we were prepared for this we were prepared for tough competition from China and we had a theory which I'll get to in a second, but everyone said, and you still hear this I can't believe you still hear this in Silicon Valley everyone said oh

don't worry about China they can't do X and sometimes X was innovate or sometimes X was like global distribution or sometimes X was marketing or sometimes X was software or design or something as far as I can tell there's no X, we haven't found an X.. DJI does all that stuff they started global they fantastic software, fantastic marketing, fantastic design they innovate.. Everyone said oh don't worry, China just just copies I don't know when that was true but that has not been true in my life since I've been paying attention.. DJI is innovating faster than everybody else.. I talked to the US trade reps and they're like so did DJI dump products under cost, do you want to file? So I said no, they kicked our ass just fair and square, and it's like, and by the way and they kept their prices higher than ours.. What they did is they just innovated faster so what they would do is they would release a product at 1500 bucks which is higher than our price and we're like uh, our product's cheaper.. Then like six months later they'd release another product at 1600, 1500 bucks or whatever and then that product they had released six months earlier goes down to 500 bucks and so they managed to get the high end of the market and the low end of market by simply iterating so fast and I'm like you know this is not dumping right this is just innovation this is, a company a country doing to Silicon Valley what Silicon Valley did to everybody else.. So what do you do about that? And the answer is we got the heck out of hardware.. There was just no light at the end of the tunnel I mean, we lost I don't know, I don't know how much we lost, we raised almost \$200 million and we, in the course of doing all this kind of stuff we spent most of it, it's some large amount that was lost in going you know, in going head to head.. GoPro lost at least \$100 million, Peretz lost \$200 million dollars I mean, there's probably, well DJI meanwhile raised about a billion dollars something north of \$10 billion valuation and everybody else just got crushed trying to kind of compete with the efficiencies of the supply chain and all that..

So we got out of hardware and that is I think, the right thing to do.. DJI created a larger I think inspired by our model they created an SDK and an API much like Apple kind of more of the Apple AppStore model than the Android model and that's good and today we use the DJI vehicles and they're fantastic and our software runs on them.. There will, as it went from the product, the hardware to the data, then things started to change a little bit.. So people are very happy to buy Chinese hardware that's fantastically good and cheap, they're less happy having their data in a Chinese server.. And so in November of last year the Department of Homeland Security banned DJI for essentially banned DJI for government use and today DJI cannot be used by the US government and increasingly other NATO governments are not allowing the use of DJI equipment.. I don't think it's fair by the way, I don't think DJI is spying, but there's a lot of paranoia about this and it's one thing to have commodity hardware, it's another thing to have data and I think that there was going to be a war and I think Great Firewall of China which is very effective at protecting the Chinese internet from outside competition, actually works both ways.. I think it'd be very difficult for Chinese cloud companies to succeed outside of China.. So I DJI is a hardware company, global first.. Alibaba, Tencent, Baidu it's gonna be difficult to see them compete outside of China despite having a fantastic technology because there's some real issues about not just trust, but also legal frameworks.. It's one thing to say hey, we have this Terms of Service we promised to do right but yeah what does the Chinese government are they comfortable with these national champions having operations outside of the rule of Chinese law..

Unclear, so I think it's a really interesting war being played out at the data side.. So I think when it comes to consumer electronics, China wins it, we're done when it comes to the software running on consumer electronics we're doing fine, like apps on Google phones which are made in China.. When it comes to enterprise grade data, that I think is still an interesting battle to be played out.. Yes in the back.. - [Man] Provide your view of where journalism is heading today.. - The question is where is journalism heading today? So I used to be an editor not a journalist, I used to be an editor in the media, I don't even know what journalism means anymore.. So, there's these words like media and journalism and it's a like a lot of other things.. There's Capital J journalism which is a kind of a pretty well-established set of church and state and you know for a Fourth Estate and responsibilities and there's like lowercase journalism which is just the Internet.. So we have the best of times and worst of times.. I think it's amazing time for writing, for personal expression, for creativity for voices to get out there and also many of those voices are accurately reporting their world..

Now their world may be the kids' soccer game, it may be something that happened on their block it may be something that happened in their company or industry and so I think lowercase, lowered, small J journalism, it's fantastic.. Capital J journalism as in sort of, newspapers with business models.. Good Luck.. I mean I got no idea what's, where there's a light at the end of that tunnel.. Um, uh, you know.. We were, I was in the magazine world which is relatively protected but you know even that's, it's based on it's based on a kind of a broken business model a hundred-year-old business model which says that basically you've got a three, a three party system you've got publishers, you've got readers and you've got advertisers.. And the advertisers, subsidized the publishing to reach the readers, and then the readers sort of implicitly promise to buy from the advertisers.. So this triangular market.. Well it turns out there's other ways for advertisers to reach readers that doesn't involve going through that third leg of the triangle and, i.e, Facebook, Google, et cetera, and they're much more effective and they're measurable et cetera.. So as banner ads died, as display ads died, as non-measurable ads died, so did the business model of traditional media, and there's a lot of experiments right now with pay walls and, if you're the New York Times, the Wall Street Journal, you'll be fine, I think Wired is now experimenting with pay wall and I think they'll be okay as well, but the San Francisco Chronicle, I don't know, I mean, I don't see how that's supported long term, and what happens as it goes away? Maybe initially we have a huge vacuum, I mean there's lots of amateur journalists who are very happy to cover the PTA meeting and the soccer game on the block..

Are they willing to cover the City Council meeting, I'm not sure.. We may have a gap.. Yes.. - [Man] The way that DIY communities got started, and the idea of reverse engineering and understanding how these established products work, were

there any legal battles that you had to fight and were there any learnings from that? - Yeah so the question is, as we kind of reversed engineered, did we have to fight legal battles? Surprisingly not.. Everyone told me that I was going to go to jail.. They couldn't decide whether it was federal jail or state jail or Guantanamo Bay, but it's like, whatever you're doing, it cannot be legal.. I mean, among other things, you're basically open sourcing weapons, is the way they saw it.. You're taking military technology and you're giving it to, I don't know, terrorists.. To say nothing of IP and all those kind of stuff and so we kept expecting the FBI, the CIA or the NSA to show up, and they did, they showed up every week, and they showed up to say, what you're doing is really interesting, can you tell us who is using your stuff? And I'm like, yeah, absolutely, it's an open community, here, there, you can read it for yourself, they're doing it in public.. And by the way if anyone's doing anything bad we'll be the first to tell you, we're totally committed to this..

And I'm like, so you don't have any problem with what we're doing, and like, I don't think it's against any laws, it's like literally every time I kept saying that, is this the time I get sent to jail, and every time they said, I think, I don't think you're breaking any laws, keep it up, just be a good citizen.. So we were.. We thought that we'd get sued on patent stuff.. Turns out that one of the nice things about disrupting an industry 30 or 40 years after it was invented is that all the patents have expired.. There was nothing, there was nothing, we never got sued.. And nobody got sued, it was the weirdest thing, nobody went to jail.. They kept, even the export control, the inspectors would come by and they're like, I don't know what you're doing but it can't be right, and we had to fight and we occasionally had to explain this and eventually the White House, it came with a white paper, that said, so literally the White House came with a white paper about DIY drones as a model of innovation and they said, this is exactly what we should be doing, it would be lowering the cost, increasing the efficiency and by the way this is consumer off-the-shelf technology.. If you can buy it in Walmart, it cannot be an export control violation.. And so we ended up spending a lot of time educating them on this but here I am, still out of jail.. - [Man] You already talked a bit about how regulation from the 70s is disrupting DIY innovators, that seems to apply to many industries..

- Is enabling, I'm sorry, regulation from the 70s disrupting DIY innovators.. - [Man] Are disrupting, blocking them from doing things.. - In our case, it was just the opposite.. Regulations from the 70s didn't anticipate the possibilities of what we were doing so we found loopholes.. - [Man] But do you think you could go farther if the regulation was not as specific.. - Yeah a little bit, yeah maybe our team won't be working real closely with the FAA et cetera, But by and large we were able to put millions of drones in the air with no changes to regulation whatsoever, just using the loopholes that were already there.. So we think of this as WiFi compared to the cell tower.. So back in the old days of wireless, if you wanted to make a radio, you had to get a license.. Broadcast license, paid billions of dollars for it.. And then the FCC in their wisdom created a sandbox of 2.4 gigahertz, and certain power limitations and spread spectrum, they said look, if you stay within these limits, you can do what you want, no license required..

And we had that, there was something called the Recreational Use Exemption and because of the radio control hobbyists, there is this little carve out for something that looks like a radio control hobby use, which is under 400 feet and visual line of sight, and it never occurred to them that the drones would, that radio control hobbyists would end up, essentially making drones.. So we didn't have to change anything.. The only exemption, the only problem was that commercial use was banned.. So recreational use was totally fine but commercial use required a special license from the FAA, and that was a real barrier towards that last step of adoption I described and so the FAA, to their credit, after they could see that there was just an untenable number of applications coming in for waivers, they created an exemption for a certain kind of commercial use, it's called Part One to Seven, if you get a.. It used to be you needed an actual pilot's license for commercial use.. So think about, when you think about 1970s regulation, think about the paradox here.. If I am a seven year old child who gets a drone under the tree and opens up the box and walks outside, you can fly, no problems.. If I'm a trained professional flying with expensive equipment, with all the gear, I am banned, and I have to get a pilot's license to do that.. So why is it that we're enabling children but banning professionals? And the answer is, you ban who you can ban.. You can't send a letter to a child, cease and desist to a child, but you can send a cease and desist to a company..

So we worked with them and we got an exemption, so we turned the pilot's license to basically a driver's license.. And that's called a Part One to Seven Exemption today that's enabled the commercial use of them.. The FAA by the way has been fantastic in this, and the FCC has been fantastic, actually the regulators have been surprisingly understanding and helpful in this and by the way you probably heard that when the Falcon Heavy launch went off, they thanked, Elon Musk was the first person they thanked, and the FAA was the second.. It's like an entity, for letting this stuff happen.. So they've been great.. Any other questions.. One in the back and then you in the middle, yes, in the back.. - [Woman] So car used to path ledgers and now they're autonomous drivers, what do you say about the future of autonomous drone driver and no pilots anymore.. - There were no pilots.. So these, the way these drones work, there's no pilots, there's no sticks, they've been autonomous for five or six years..

- [Woman] Drone pilot like recreational racing.. - They pilot because they wanna pilot.. So drones haven't needed pilots for most of the decade.. The way it works right here is that you just push, there's an iPad and you just press a button and say go, and it does an autonomous mission.. So there's no sticks, there's no piloting, it just does its own thing, it does it every hour, so it's like a sprinkler.. So for commercial use, they've been autonomous forever.. But what you're describing, things like drone racing, those aren't actually drones.. Those are called remotely piloted vehicles, but drones are autonomous.. And cars by the way, are just the opposite, cars are actually gonna maintain a driver for a long time because again, there's a human on board and so there's a much higher risk, a much higher requirement to have a fallback on, so called human in the loop fallback, for

safety.. Right now, if anything were to go wrong here, there has to be human presence, there has to be a human in the vicinity who could take over control in case something went wrong, they never do..

With a car, it's quite important that the human be able to take over control instantaneously because the humans on board, at risk.. There was a question in the middle, yeah.. Yeah, this is the last question.. - So you talked about, for drones, when you talked the new hobbies and automobiles, you also talked about the risk when you put a human on board and what's at stake with that.. Do you think that there'll be kind of a segregation of solutions and markets where, there's one where you have the high risk tolerance and you fail fast, but then those devices or solutions would have to be kept away from where they can do the harm, and the ones where humans will be exposed to the risk or on board or what not, we just go Rainbow and (mumbles).. But these markets really won't have an intersection per say, so the Venn diagram won't go to the left, if you see like in a decade or more that failing fast and doing it at an order of magnitude cheaper will eventually subsume that, now that the Rainbow one is really only a cheaper rate thing.. - It's a really good question.. So there's three domains, there is the domain of little things flying autonomously without people involved, there's not people on them, there's not people underneath them, they're just doing their thing.. Then there's when you have little things, and maybe even big things with no people on board but there's people on the grounds who could be hurt and then there's things where you've got people on board.. So the first one of little things flying around, not around people, that's solved, we do that everyday..

The second one of little things flying over people, we're just getting permission to do that.. So the second iteration of that is bigger things, with no people on board, but flying over people and that's like drone delivery, like Amazon drone delivery, Google drone delivery.. And we're still trying to figure out the rules on that but probably the easiest way to do is not fly over people like fly over water, things like that, et cetera.. And that's probably in the next five years.. Then you get to the big things, with people on board, also flying over people, and that's the air taxi scenario.. That one's gonna be tough.. I'm one of the advisors on a bunch of several companies in this space, Uber's got a conference every year that (mumbles) about this in particular.. One thing we talk a lot about is the red button.. So you're now in an Uber air taxi.. So you took out your app, you said I wanna fly to San Francisco, and so it tells you that there's a rooftop around here somewhere and you just get to the rooftop and the thing descends, you get in, you take off, you're now on your way to San Francisco..

Is there a red button? So if you get in an elevator, there's a red button you can press if you're not happy.. A lot of machinery has kill switches there, is there a red button? If things are not going well, is there a red button? And this is an interesting one to think about because, let's say there's no red button, how do you feel about that? You're completely helpless right, there's nothing you can do.. Let's say there is a red button, how do you feel about that? What if you press the red button, what's supposed to happen? Does the red button do anything, in which case, maybe a parachute comes out and you then gently land on top of a bunch of people, that would suck, for them.. Maybe the red button is just like the red button in the elevator, it doesn't actually do anything but it just rings a bell at headquarters and headquarters says hey, what's up, uhm, maybe there's, maybe the red button instantaneously switched into some manually piloted mode but if a motor just died it's not gonna do any good, we haven't figured out what should happen.. When you think about just the psychology and the sort of negative externalities of the red button, it's super tricky, especially when there's no pilot on board.. So that one, I mean, we're not gonna solve it globally, we're gonna solve it in specific places so like, Dubai will say, we're totally cool with it.. Air taxi from Dubai Airport to (mumbles) or whatever, we're cool.. New York may not say that for decades.. But I think really, the future's already here, it's just unevenly distributed.. (audience applause)..