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3D Robotics:
Disrupting the Drone Market

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Chris Anderson

This case study focuses on 3D Robotics, a drone company with UAV platforms. It examines what 3DR should pursue at the critical inflection point within its history and highlights what is unique about 3DR, particularly when compared to a more traditional non-open, non-Maker company. (Keywords: Entrepreneurship, Corporate Strategy, Market Entry, Open Source, Innovation, Crowdsourcing)

"Ultimately, the way society best figures out how to think about a powerful new technology is to set it free and watch where it flies."—Chris Anderson, 3D Robotics CEO[1]

"Chris Anderson is incredibly special because he is not just creating a product, he is creating a movement."—Jon Callaghan, True Ventures[2]

On a sunny, brisk spring day in 2014, Chris Anderson, CEO of 3D Robotics (3DR), a developer of drones, was squinting as he looked towards the sky at a small flying black and blue object with four spinning propellers. He was in the grassy patch outside their office testing the IRIS, a small drone that flew autonomously[3] via an Android tablet, phone, or laptop. Remarkably, it could be programmed to takeoff and fly from precise point A to B, avoid obstacles through sensors, and land on its own.

While the word "drone" (or Unmanned Aerial Vehicles—"UAVs") conjured up images of stealthy military crafts zipping around in secret unmanned missions, Anderson, former *Wired* Magazine Editor-in-Chief,[4] was changing that perception through 3DR, the company he had co-founded in 2009. 3DR was an example of

Several quotations, as noted, are taken from Chris Anderson, *Makers: The New Industrial Revolution* (Crown Business, 2012), by permission of Penguin Random House.

The full case study version of this article is available through the Berkeley-Haas Case Series at <http://cmr.berkeley.edu/berkeley_haas_cases.html>.

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Chris Anderson is the CEO of 3D Robotics and founder of DIY Drones. From 2001 through 2012 he was the Editor in Chief of *Wired* Magazine. He is the author of the *New York Times* bestselling books *The Long Tail and Free* as well as *Makers: The New Industrial Revolution*.

the manufacturer of the future—a modern-day hardware designer that coordinated a large community of open source software developers who supported its devices. Anderson described the company as "using the software of today to build the hardware of tomorrow."[5]

The company, which initially targeted hobbyists, was exploring commercial uses in market segments that did not require FAA[6] approval. At the time of this case, drones were only permitted for personal use in the U.S. and were restricted to heights of 400 feet, to be within visual line of sight, and remain away from populated areas and airports. However, the FAA did offer special permits for commercial use (since 2009, the FAA has issued 1,387 of these Certifications of Authorization for limited UAV flights to government, educational, and research entities, and as of December 2013, there were 545 active permits).[7] The FAA was considering commercial use of drones to begin in 2015, but was cautious due to safety concerns.

3DR's UAV platforms captured breathtaking aerial imagery for consumer enjoyment and data analysis, enabling mapping, surveying, 3D modeling, and more for possible commercial applications such as agriculture, photography, surveillance, search and rescue, construction, and ecological study. The worldwide drone industry was estimated by some to be $6 billion in 2013 and expected to grow to more than $11 billion over the next decade.[8] Some estimated market figures were much higher (see below). Amazon's release on December 1, 2013 of an 80-second video and a 60-Minutes interview highlighting what drone package deliveries might look like (Prime Air program) undoubtedly contributed some hype to market assessments.[9]

By 2014, 3DR had 200 employees in North America with a research and development office in Berkeley, California, and a manufacturing facility in Tijuana, Mexico (that manufactured ready-to-use drones that sold for as little as $400). The company had sales of $10 million on 30,000 orders in 2012,[10] and over $20 million in 2013 by charging for the hardware and "giving away the bits [design files, software, etc.]"[11] to its 28,000 customers worldwide who also bought motors, batteries, cables, and propellers from 3DR. 3DR's product line included a single plane-style drone, four copter drones, and IRIS, its new consumer drone (Exhibits 1 and 2).

EXHIBIT 1. 3DR Financials

Rudimentary, fictional income statement (in thousands $US)

Year	2013	2012	2011
Total Revenue	**20,000**	**10,000**	**5,000**
Cost of Revenue	11,000	6,000	2,900
Gross Profit*	**9,000**	**4,000**	**2,100**
Operating Expenses			
Research/Development	10,000	3,000	1,700

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Selling General and Administrative	4,000	1,000	300
Non Recurring	–	–	–
Total Operating Expenses	–	–	–
Operating Income or Loss	**−5,000**	**0**	**100**

Source: 3DR.

*3DR estimated that industry gross profits were around 35%.

EXHIBIT 2. Funding History and Cap Table

Round	Date	Amount	Investors
Self-Financed		$50,000	
Series A	11/5/12	$5.1 million	True Ventures, O'Reilly AlphaTech Ventures, and others
Series B	9/12/13	$31 million	Mayfield Fund ($6 million), Foundry Group, True Ventures, O'Reilly AlphaTech Ventures, and others

Fake Cap Table:
1,000,000 shares total

Chris Anderson: 200,000
Jordi Muñoz: 200,000
True: 180,000
OATV: 90,000
Foundry: 80,000
Mayfield: 50,000
Other investors: 100,000
Options pool: 100,000

Source: 3DR.

As Anderson's eyes were riveted by each subtle movement of the IRIS, he was excited about the future of 3DR and amazed at the drone boom he and 3DR helped to create. In his head, he replayed a scenario that he'd been frequently mulling over: "We need to be the future of *x*." One of his critical tasks over the next few months was to figure out, what is *x* going to be?—big data (e.g., agriculture, climate, search and rescue), personal aerial cinematography, or something else? Moreover, there was additional urgency in this decision because the competition had come on strong. In particular, the Chinese company DJI's Phantom 2 personal drone had snuck up to dominate the market, which concerned Anderson and his team. DJI had raced to nearly 20 times the size of 3DR with 1,600 employees, 400 engineers, and over $500 million in revenue

and focused entirely on drones for commercial and consumer markets. "At first, investors thought drones were not a market," he said. "Then around nine months ago, they realized they were one. Now the question is, will we be the leader?"[12]

The Maker Movement

The internet democratized the tools both of "invention *and* of production," according to Anderson. Now anyone could use software and new production tools to design and manufacture a physical product and "ship it" to people around the world. In essence, the internet liberated this world of "bits."

The internet's model of innovation spurred entrepreneurship and economic growth, democratizing publishing, broadcasting, and communications that led to an increase in participation in everything digital—the Long Tail of bits, according to Anderson. Consumers' wants could now be met in ways that physical stores could not. Anderson cited Amazon, which could list many more products than any physical retailer could carry, as an example. He argued that products no longer needed to sell in large quantities and instead, companies could use the internet to reach the increasingly discriminating consumer who follows social media and word of mouth to buy specialty products online.

And the Web revolution went beyond just the ability to buy more things with greater choice. It allowed people to "make our own stuff" that others could consume, such as videos on YouTube, words (blogging), and pictures. "If you had talent and drive, you could find an audience, even if you didn't work for the right company or have the right degree."[13]

Beyond the world of bits lay an entire massive world of "atoms," or the real world of products and things. "Just imagine what a similar model could do in the larger economy of Real Stuff…the Long Tail of things...the shift in culture toward niche goods."[14] This new world was what Anderson called "The New Industrial Revolution."

"The past 10 years have been about discovering new ways to create, invent, and work together on the Web. The next 10 years will be about applying those lessons to the real world," he said.[15] By real world, Anderson was referring to physical products that—because of expertise, equipment, and costs of production on a large scale—had been closed to the pursuits of hobbyists and even entrepreneurs. He said: "Physical products are increasingly just digital information put in physical form by robotic devices…hardware is mostly software these days, with products becoming little more than intellectual property embodied in commodity materials….In short, the reason atoms are the new bits is that they can increasingly be made to *act like bits*."[16]

In this new world, anyone could invent or design something, upload files to a service to have the product made, or even make it themselves on a 3-D printer (an industrial robot that could make three-dimensional solid objects of virtually any shape from a digital model). Any designer now has the ability to quickly experiment with new product designs using such 3-D printers.

These changes drove a new social movement aptly called the "Maker Movement" where participants could make things ranging from crafts to advanced electronics (Exhibit 3). Makers used digital desktop tools to create designs for new products. The "making" part of the Maker Movement could start with a 3-D printer like MakerBot, a Brooklyn-based company that for six years has been building inexpensive 3-D printers in an open source development model, much like 3DR. Its latest products had an easy to use system, driven by a simple desktop application that allowed users to turn CAD files into physical things just like printing a photo.

EXHIBIT 3. Open/Maker Example: MakerBot Industries

MakerBot Industries is a Brooklyn, New York-based company that made 3D printers. It was founded in January 2009 by Bre Pettis, Adam Mayer, and Zach Hoeken Smith (he was one of the founding members of the RepRap Research Foundation, a non-profit organization that advanced research in open-source 3D printers). Seed funding was provided by Jack Lodwick ($50,000) and Adrian and Christine Bowyer ($25,000). In August 2011, the Foundry Group invested $10 million and joined the board. As of March 2011, the company had sold 3,500 units and by 2012, more than 5,200 MakerBots had been sold. Revenue in 2013 was $75 million, and the company had sold more than 22,000 units. On June 19, 2013, Stratasys Inc. acquired MakerBot in a stock deal worth $403 million based on the share value of Stratasys, making MakerBot a subsidiary of Stratasys. Stratasys paid $403 million in exchange for 100 percent of MakerBot's stock. The remaining two-thirds of the deal (a $604 million total deal) would be subject to MakerBot's performance over the following two years.

Early on, MakerBot made the first mainstream $1,000 3D printers. Rather than using laser, the MakerBot Thing-O-Matic printer built up objects by squeezing out a 0.33-mm-thick thread of melted ABS plastic, which comes in multi-colored reels. MakerBots were personalized and decorated with Day-Glo letters.

MakerBot was designed by a community, built upon several previous open-source projects such as RepRap mentioned above, the Arduino microprocessor board, and a series of software packages that turned CAD files into instructions for the three motors that controlled a 3-D printer's motors. Anderson said: "In this case, open source means open everything: electronics, software, physical design, documentation, even the logo….It is a shining example of how abandoning intellectual property protection can actually grant even more protection in the form of community support and goodwill."**

By 2014, MakerBot had numerous products like the MakerBot Replicator Mini (compact 3D printer), MakerBot Replicator (desktop 3D

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printer), MakerBot Replicator Z18 (3D printer), MakerBot Replicator 2 (desktop 3D printer), MakerBot Replicator 2X (experimental 3D printer), and the MakerBot Digitizer (desktop 3D scanner).

Source: Various.
**Chris Anderson, Makers, 2012, p. 94.

Anderson added: "And what's clear about these new producers is that they're not going to be making the same one-size-fits-all products that defined the mass-production era. Instead, they're going to be starting with one-size-fits-one and building from there, finding out how many other consumers share their interest, passions, and unique needs."[17]

Makers could even share production spaces around the world called "makerspaces" like TechShop,[18] "a vibrant, creative community that provides access to tools, software and space," started by a former executive of Kinko's printing and copying. The Maker Movement also encompassed Etsy, for example, a web marketplace for Makers who sold arts and crafts and many other homemade things, as well as included the Maker Faire, "the Greatest Show (and Tell) on Earth—a family-friendly festival of invention, creativity and resourcefulness, and a celebration of the Maker movement."[19] Many Maker companies started as hobbies and even raised money on crowdfunding sites like Kickstarter.

"Today, the Maker Movement is where the personal computer revolution was in 1985—a garage phenomenon bringing a bottom-up challenge to the ruling order of the time," said Anderson. "The great opportunity in the new Maker Movement is the ability to be both small *and* global. Both artisanal and innovative. Both high-tech and low-cost. Starting small and getting big….The shape of the twenty-first century's industrial structure will be very different from the twentieth century's. Rather than top-down innovation by some of the biggest companies in the world, we're seeing bottom-up innovation by countless individuals, including amateurs, entrepreneurs, and professionals. We've already seen it work before in bits….Now the conditions have arrived for it to work again, at an even greater, broader scale, in atoms."[20]

Anderson emphasized that it was in the *how* prototypes could be made today that made all the difference: "As we've learned over the past few decades, digital is different."[21] The fact that digital files could not only be shared and copied, but more importantly, modified, led to an open and collaborative culture.

New Open Source Culture

But Makers didn't just make things. They could now share those designs and collaborate with others in online communities (an example was the rise of "open hardware" companies, like open source software and communities that launched Firefox or Linux) where makers launched companies like Arduino electronics development board, Google with its Android mobile operating system, open source cars, watches like Pebble, toaster ovens, and 3DR itself.

Anderson called this new culture, a "remix" culture where he said the ability to easily "remix" digital files "is the engine that drives community….You don't need to invent something from scratch or have an original idea. Instead, you can participate in a collaborative improvement of existing ideas or designs. The barrier to entry of participation is lower because it's so easy to modify digital files rather than create them entirely yourself."[22] Anderson added: "When you share, community forms. And what community does best is remixing—exploring variation in what a product can be, and in the process improving it and propagating it far faster than any individual or single company could."[23]

This meant that anyone could join and contribute to the community, no matter where they were located or what their background was. "Amateurs have as much influence as professionals," said Anderson. "The same is true in almost any open-innovation community: when you let anyone contribute and ideas are judged on their merits rather than on the résumé of the contributor, you invariably find that some of the best contributors are those who don't actually do it in their day job….What this taps is the Long Tail of talent; in many fields, there are a lot more people with skills, ideas, and time to help than there are people who have professional degrees and are otherwise credentialed. Exposing this latent potential, both of professionals looking to follow their passions rather than their bosses' priorities and of amateurs with something to offer, is the real power of open innovation."[24]

And because such communities did not operate in the Coasian[25] model where people worked for a firm, such organizations did not miss out on attracting the "cake maker, the graphics artist working for the Brazilian ad agency, the guy who runs the Italian ambulance radio company, the retired car-dealership owner, the Spaniard working for an energy company in the Canary Islands, and all the others who followed their passions even though their careers had taken them elsewhere."[26] With such a community, an organization could work with smarter people while minimizing transaction costs with technology, not proximity. "A social network is our common roof. Skype is the 'next cubicle.' Our shared purpose is really shared, not dictated."[27] In such an environment, the atoms are Coasian, but the bits are Joyian.[28]

Anderson said on the potential of open communities: "When you release your designs on the Web, licensed so that others can use them, you build trust, community, and potentially a source of free development advice and labor…. The result: hundreds of people [can] contribute code, bug fixes, and design ideas, and have made complementary products to enhance our own. The simple act of going open source…provides an essentially free R&D operation that would cost a great deal in closed-source development models."[29]

New Manufacturing Model

Makers could produce their products much more easily in this new environment. They could use common design file standards that could be sent to web-based on-demand commercial manufacturing services to be produced in any number. In essence, given the ease of 3-D printing and desktop fabrication,

along with easy access to manufacturing capacity, anyone could start a business making real things.

"The barriers against entry to entrepreneurship in physical goods are dropping like a stone," said Anderson.[30] Thus, would-be entrepreneurs and inventors were no longer at the mercy of large companies to manufacture their ideas. Anderson said: "Manufacturing has now become just another 'cloud service' that you can access from Web browsers, using a tiny amount of vast industrial infrastructure as and when you need it….All those niche products that either weren't on the market at all because they didn't pass the economic test of mass production or were ruinously expensive because they needed to be handmade are now within reach….With digital fabrication, it's the reverse: the things that are expensive in traditional manufacturing become free (variety is free, complexity is free, and flexibility is free)."[31] "All of this has given designers and engineers a fast-forward button advancing this technological flip-flop."[32]

This new manufacturing model had "to incorporate all the skills and learning of traditional manufacturing companies—tight quality control, efficient inventory management, and supply-chain management—so that it can compete with them on basic price and quality. But it also needs to incorporate many of the skills of Web companies in creating and harnessing a community around its products that allow it to design new goods faster, better, cheaper. In short, it must be like the best hardware companies *and* the best software companies. Atoms *and* bits."[33]

On manufacturing and China, Anderson argued that at some scales, manufacturing in huge Chinese factories will continue to make sense. But at other scales, the advantages of making things close to home, with minimal delays and maximum flexibility, could be a better choice.[34] He gave an example where a company might outsource manufacturing to China at launch because they didn't have manufacturing capacity. But when the product reached the hundreds, it would take months for a new supply to arrive and the manufacturer might require larger order quantities, tying up the company's capital. This might lead to a shift back to local manufacturing to manage inventory and make more efficient product improvements. But when sales reached into the tens of thousands, the company might shift back to China since the 30 percent cost advantage might begin to become more attractive with larger volumes. "Companies can increasingly move manufacturing to wherever it makes most sense," he said. "They can do so because the design files are digital, the tooling costs of setting up a new manufacturing operation are minimal, and they all use the same robotic machinery, which can be bought anywhere."[35]

Phase One: DIY and an Open Source Community

The "Aha Moment"

One day, Anderson, who has a degree in physics and has conducted research at the Los Alamos National Laboratory, brought home from the *Wired* offices a Lego Mindstorms robotics kit and a ready-to-fly radio-controlled airplane with the goal of working with his five kids on the projects over the weekend. Unfortunately, the kids weren't impressed with the limited capabilities of the Lego kit. "Hollywood, it turns out, has ruined robotics for kids, who now expect laser-armed humanoid

machines that also transform into trucks," Anderson joked.[36] Similarly, the kids were not impressed with Anderson's airplane, which he crashed into a tree at a local park.

Miffed and puzzled, he went for a run and started thinking about the impressive range of sensors that the Lego Mindstorms robotics kit had, with its accelerometers (tilt sensors), electronic gyroscopes, a compass, and a Bluetooth link that could connect to a wireless GPS sensor. "It occurred to me that those were exactly the same sensors you'd need to make an airplane autopilot. We could solve both problems at once: build something cool with Mindstorms that had never been done before and get the robot to fly the plane!"[37]

When Anderson returned home, he prototyped a Lego autopilot on the dining room table and his 9-year-old helped to write the software. They posted some pictures on the internet and their project was on the front page of tech website, *Slashdot* that evening. "We put it in a plane—the world's first Lego drone, I think—and took it out a few weekends later," said Anderson. "It almost-kinda worked, staying aloft and steering on its own, albeit not always to the places we told it to go."[38]

After a few more weeks of tinkering, Anderson developed a Lego autopilot that had most of the functionality of a professional device, if not the performance. But it became clear to him that Lego Mindstorms, for all of its charms, "was too big and expensive to serve as the ideal platform for homemade drones."

DIY Drones and the Online Community Platform

In 2007, Anderson decided to post his work and questions online, not with a blog, but through an autonomous aircraft nonprofit social network he created for the purpose, called DIY Drones (diydrones.com)—a place where hackers and makers could swap tips on how to build and fly unmanned aerial vehicles. "That distinction—a site created as a community, not a one-man news and information site like a blog—turned out to make all the difference," he said.[39]

On the DIY Drones community, Anderson said: "I was blown away by what people in our community were doing with sensors from mobile phones and chips that cost less than a cup of coffee. Feature by feature, they were matching—or besting—aerospace electronics that had cost tens or hundreds of thousands of dollars just a decade earlier. It felt like the future of aviation."[40]

"Initially, members would just post code and design files for their own projects, showing off for each other in a form of nerd braggadocio," said Anderson. "But over time, we set up more organized systems of collaboration, including version control systems and file repositories, wikis, mailing lists, and formal team assignments."[41] The DIY Drone community participants eventually had access to a full range of authoring tools, could comment, blog, start discussions, upload videos and pictures, create profile pages, and send messages. On structure within an open source community, Anderson joked: "The reality is that behind every great open source or open innovation project, there is a malevolent dictator."

A few months after DIY Drones launched and had a few hundred members, Jordi Muñoz, a 20-year-old electrical engineer who was waiting for his green card

in Riverside, California (after leaving Mexico to live with his wife, a U.S. citizen) signed up and posted a link to a "cool hack he'd done with a new open-source microprocessor board called Arduino," said Anderson.[42]

"I was extremely bored," Muñoz said. "I could only watch TV or program something, so I decided to program."[43] He had spliced motion sensors of a Nintendo Wii controller with a mini copter and worked on his project for eight months, the "most productive months" of his life where he was able to stabilize the helicopter's flight using computer code. It was the perfect marriage between his obsession with computer technology and his childhood dream of becoming a pilot.

Anderson had become so impressed with Muñoz's work that they began to collaborate virtually. He said on Muñoz: "He was able to quickly learn about very advanced technology. He did all that by teaching himself on the internet. He's that generation of people who don't know what they don't know. He didn't know he was supposed to have a Ph.D. to invent a drone. He just did it."[44] They worked on projects together such as an airplane autopilot and an autonomous blimp controller board. By March 2014, DIY Drones was the largest robotics community in the world with around 50,000 active members and two million page views per month with a comment every minute on the site.

Phase Two: Ready to Fly—Launching 3D Robotics

A Cottage Industry

As Anderson and Muñoz continued to work together, they realized that they needed to start offering kits with everything included. They started collecting parts to make an aerial robot kit, buying electronic parts in volume from around the world and sending the circuit-board design files off to be fabricated. Initially, Anderson hand-soldered a few dozen boards himself, then found a student on Craigslist to do a hundred more, and finally contracted with an assembly firm to do a few hundred more. He then loaded the software onto the boards and packed the kits with the help of his kids.

Their next product was an airplane autopilot board, where they partnered with Sparkfun (a designer and manufacturer of electronics for open-source hardware communities). "Because they handled all the sourcing and manufacturing, our community could spend its time working on R&D and bear no inventory risk," said Anderson.[45]

At some point, things changed though: "We realized we had a drone innovation platform and we should probably start a company."[46] In 2009, when it became clear to Anderson that there was a group of people who didn't want to build drones, but would buy them finished, the two co-founded 3D Robotics, even though they had not yet met in person. Initially Anderson remained as Editor of *Wired* and served as the non-executive chairman of 3DR, while Muñoz focused on building the product and served as the CEO. The company was profitable in its first year of operation, on $250,000 in revenue.

They wanted to run the company in an open source "community-centric" way where they sold drone products through a website, but had a chatty blog with tutorials and videos from employees and stories about customers and users, and customers helping each other on DIY Drones. "When a consumer buys a drone, they

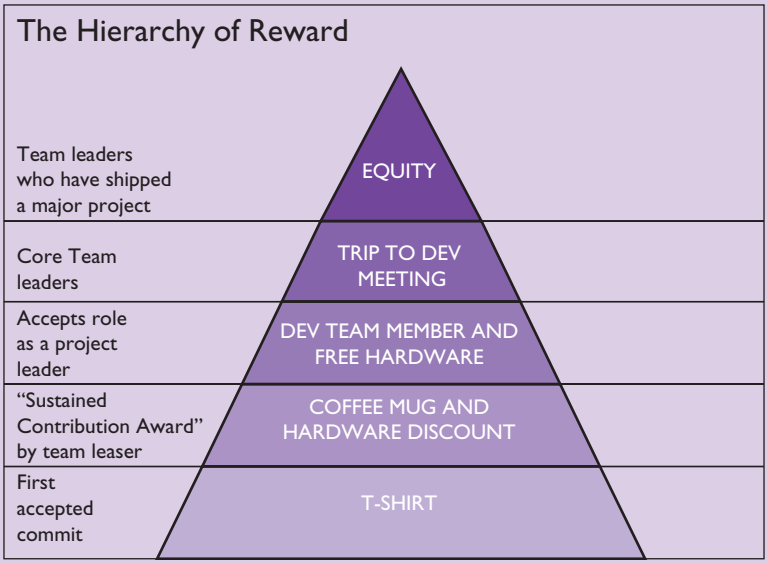
would plug the hardware in, and from the internet, download free software from our community, which turns the hardware into a drone," said Anderson.

As demand grew, Anderson and Muñoz moved the operation to commercial space in San Diego to be closer to low-cost labor in Tijuana, Mexico, and began acquiring automated manufacturing tools. Quickly, the team outgrew that space and expanded into the bigger space next door.

Leveraging the Community

3DR invested around $2 million per year into its development team (including documentation work), and Anderson felt that the company was extracting multiples of that in value from the community because the vast majority of contributors were not paid. In fact, most community members worked for 3DR for free (or for small rewards like T-shirts, coffee mugs, and hardware discounts), but at the highest levels, some team leaders were given trips to development meetings and those who actually helped to ship a major product received equity in 3DR (Exhibit 4). Moreover, every single one of 3DR's paid software developers came out of the community. "I've never met most of them," said Anderson. "They've earned their way by becoming respected and doing good work."

EXHIBIT 4. 3DR's Reward System



Source: Chris Anderson, Makers, 2012, p. 111.

Of course, products created in such an open source environment did not enjoy the legal protections of patented inventions. As an example, in 2011, a graduate student in China translated a manual for a 3DR UAV to help people who bought a Chinese version of the machine. Anderson said he was "angry—at first. But then I

realized it was helping us. Our policy of open software and open hardware almost welcomes copycats." So he put a link to the translation on his site and the student started making corrections in the manuals (both English and Chinese) and fixing bugs in the code itself. "Today he is one of our best development team members," said Anderson.[47]

This approach was new, Anderson said: "Open hardware, drones, and the future of robotics; merging the community and the company. If we get it right, it'll be a fantastic model for companies of all sorts; if we get it wrong, an instructive failure."[48]

"Hardware is the New Software"

The explosion of smartphones and components was what drove the growth in the drone market because they helped to make drone parts smaller, better, and more energy efficient—and thus more affordable. Anderson explained: "All the components in a smartphone—the sensors, the GPS, the camera, the core processors, the wireless, the memory, the battery—all that stuff, which is being driven by the incredible economies of scale and innovation machines at Apple, Google, and others, is available for a few dollars. They were essentially 'unobtainium' 10 years ago. This is stuff that used to be military industrial technology; you can buy it at RadioShack now," thus making it easier than ever to construct hardware that could interact with the outside world in a fully or partially autonomous way. Anderson said the industry was going through a Moore's-law-style pace where performance doubled while size and price plummeted.

The smartphone sensors Anderson was referring to were available at RadioShack. They included gyroscopes, which measure rates of rotation; magnetometers, which function as digital compasses; pressure sensors, which measure atmospheric pressure to calculate altitude; and accelerometers, to measure the force of gravity. A standard smartphone had a full suite of such sophisticated sensors to detect position in games, maps, and augmented reality. "In short, this new generation of cheap, small drones is essentially a fleet of flying smartphones. More and more, autopilot electronics look just like smartphone electronics, simply running different software."[49]

Sensors and other devices that collect data and information and transmit such data via the internet are referred to as "The Internet of Things." One of myriad examples is home sensors connected to smart phones so that people can control heating or lighting through their phones. According to *Business Insider*: "There is a strong intersection between drones and The Internet of Things, as more devices become internet-connected and are operated remotely, often by smartphones or tablets. Drones can be viewed as the ultimate mobile internet-connected object, and many of the technologies that will be used in the Internet of Things may eventually incorporate information received from drones."

On the processors, Anderson explained further: "Meanwhile, the brain of an autopilot—the 'embedded computer,' or single-chip microprocessor, that steers the plane based on input from all the sensors—has undergone an even more impressive transformation, thanks to the rise of the smartphone….The result was a shift to the

hyperefficient 'reduced instruction set computing' architectures—led by British chip designer ARM, which now dominates the single-chip industry—driving the performance gains of our smartphones and tablets. As it turns out, these chips are also perfect for drones: fast and power-efficient processors mean that they can go beyond simply following a pre-programmed mission and start to think for themselves."[50]

Because the technology to make drones had become available to everyone, Anderson believed innovation in the field was dramatic, akin to what had occurred when personal computers emerged in the late 1970s, as well as the emergence of the internet. And he believed drones were a disruptive innovation: "I'd define disruption as 'Order of Magnitude innovation.' Products or services that are factors of ten cheaper, faster, better, smaller, or easier to use. When you throw that kind of innovation into a market, it is intrinsically disruptive (usually to the benefit of consumers)."[51]

Anderson's big insight, according to Mayfield Fund's Tim Chang, was that people actually don't want to learn how to pilot drones or become pilots. "They just want to use the drone for what they already want to get done. So if the drone can fly itself and if it has the best autonomous autopilot, that's when you open up all sorts of new markets." With that insight, 3DR always had a deep focus on autonomous autopilot capabilities, "which was essentially a software problem, not so much a hardware problem," said Chang. "There are a lot of competitors that can throw together a pretty drone and get the hardware done, but the software, the autonomous part, that's some pretty hardcore artificial intelligence and it takes years and years of algorithm, software, and data science development and that's where you will always stay a step or two ahead of your competition if your competition tends to come from the hardware world."

A New CEO

3DR continued to grow very quickly and by 2011, had $5 million in revenue and in 2012, over $10 million, with most sales coming from overseas since commercial use of drones was still banned in the U.S., pending new rules from the FAA. By November 2012, 3DR had 40 employees and planned to hire more hardware and software engineers in San Diego/Mexico and sales, marketing, and community management people in the Bay Area.

Muñoz had shepherded the company through its first years but in 2012, Anderson left *Wired* to lead 3DR full time as the CEO and Muñoz assumed the title of President, overseeing operations. "Jordi had essentially de-risked this thing for me," said Anderson. "I don't know how I did it, but I found the right guy on the internet. At that point, I knew this was a real company and that I should follow my heart." Andy Jensen, 3DR's CFO said: "When Chris signed on fully, we were shifting from bags of parts to more cohesive grouping of parts. It's still DIY, but we're talking about systems instead of components."

Manufacturing Strategy

3DR's robotics factory in Tijuana, Mexico was just 20 minutes away from its original factory in San Diego. Originally, 3DR planned to have manufacturing

in Tijuana and engineers in San Diego, but gradually shifted to having engineers in Tijuana as well. "The reason we have a Tijuana manufacturing facility is because Mexico graduates more engineers than the United States, and Mexico's number one export is actually electronics," said Anderson. "The last 500 years of globalization were driven by money and cheaper labor. This era of globalization will be driven by time, faster and faster innovation, and the way you do that is a shorter and shorter supply chain."

On why 3DR did not immediately source products through China, Anderson said it wasn't based on cost, but this idea of a shorter supply chain: "The salaries in Tijuana are about half the U.S. rate ($1,200 a month), which is just three times the price of China. For one of our products, such as a $200 autopilot board, the difference in labor costs between making it in Mexico and making it in China amounts to less than a dollar, or about one percent of the product's cost (and half a percent of its retail price). Other costs, such as rent and electricity, are even closer to Chinese levels."[52]

Chang called Anderson's decision to launch in North America and avoid China a smart decision: "This is really a big case study on the rise or return of Made in North America. All my other startups had lost 6 to 18 months trying to get launched in China or Taiwan and it's because of language, time zone differences, and bad business ethics where your vendor will screw you and you can't sue them. I think more and more hardware startups are finding that starting in China is much harder than they expected and it's probably a train wreck waiting to happen."

Phase Three: Software Platform and Markets

As the company continued to grow, Anderson and his team faced their next set of challenges. "We created the community, then the product, and the next question was, 'What's it good for?'" asked Anderson. What came next was the platform, the software that made drones "useful to people in the real world," he said.

Although the company had focused on both the consumer and the enterprise/commercial markets, it had emphasized building a strong product for consumers due to ambiguity with FAA regulations. Jensen stated that selling many units to one customer "might be an indicator that someone would be buying our drones for commercial purposes." However most of 3DR's sales were not for many units. He added: "But we have many conversations with people in enterprise who are trying to figure out how to use drones in their businesses and they do buy from us for exploratory purposes."

Anderson said on the consumer market: "The good news is that very few companies can be in the consumer space (e.g., aerospace companies could not be in the consumer space) so the vast majority of our competitors and others like Trimble,[53] a GPS company, and Parrot,[54] a consumer technology company are partially sitting on the sidelines because they expected the commercial market to take off sooner, whereas we bet on the consumer and that was right."[55] 3DR's largest and most formidable competitor at the time of this case was China-based DJI (Exhibit 5).

EXHIBIT 5. DJI Profile

Products:

- 5 Ready-to-Fly drones ($499 to $1,200) available on DJI's website
- 4 Flying Platforms (for high-level professional aerial photography and cinematography at $2,000 to $6,000) available through dealers
- Multi-rotor and Helicopter Flight Controllers available through dealers
- Camera Gimbals, and Accessories ($2,000 to $3,000) available through dealers

Revenue: $131 million

Employees: 900 in China, Japan, Europe, and the U.S. with 30 researchers in Hong Kong (many of them students or graduates of Hong Kong University of Science and Technology)

R&D: Unknown

Source: http://www.scmp.com/news/hong-kong/article/1370451/apple-pearl-river-delta-dji-innovations-taking-flight, *December 2, 2013.*

Anderson sought to build a good product for the consumer first because he believed that what worked for the consumer would work for commercial, but not the inverse. "You can make something easy yet powerful, but it's hard to make something powerful easy to use," he said. So if it works for a 9-year-old, it will work for a farmer."

Manufacturing Shift

As time went on, however, Chinese competitor DJI released its Phantom 2 consumer drone with a built-in camera and other capabilities. In 2014, Anderson decided to shift 3DR's consumer manufacturing strategy to China, while the enterprise manufacturing would remain in Tijuana. The non-recurring engineering costs to set up this new manufacturing arrangement were estimated at $1 to $2 million.

Anderson said on the switch: "Mexico was cost competitive with China until we got up against this class of product [DJI's Phantom] which uses technology and production techniques we don't have in Tijuana. The injection molding and cabling is terrible in Tijuana, batteries are not available, and motors aren't made there."

In hindsight, Anderson would have still launched 3DR's manufacturing in Mexico for "innovation reasons." He said: "When we didn't know what we were doing, we had to keep changing and changing and changing. Had I locked the design down early and had 60,000 units batch-manufactured in China, they would have been stuck on a container ship and we would have had to wait six months and I would have had 60,000 broken products that I couldn't sell. During the high period of our innovation cycle, we needed that tight connection between the engineering and manufacturing. Now that our innovation cycle has slowed

down—we rev them every six months, not six days—we have confidence to batch produce in China."

Potential Markets

As Chris Anderson, Andy Jensen, and Mayfield's Tim Chang sat in 3DR's offices to discuss the next phase of the company, they began talking about different opportunities, given the potentially large drone market. In fact, according to a study by the Association for Unmanned Vehicle Systems International (AUVSI), the Unmanned Aircraft Systems (UAS) industry in the U.S. could produce 100,000 new jobs and add $82 billion in economic activity between 2015 and 2025.[56] The AUVSI also predicted that the economic impact of UAS in the first three years after FAA regulatory changes could be $13.6 billion. According to the report, precision agriculture and public safety would make up more than 90 percent of this growth: "The commercial agriculture market is by far the largest segment, dwarfing all others." *Business Insider* estimated that 12 percent of a potential $98 billion in cumulative spending on aerial drones over the next decade would be for commercial purposes. (Exhibit 6).[57]

EXHIBIT 6. Potential Markets

Security and Monitoring: Drones could complement or replace static security cameras. In New York, for example, former Mayor Michael Bloomberg said drones will ultimately supplement or replace the many security cameras operating throughout the city. Security drones might also replace or supplement foot and vehicle patrols at large commercial facilities like factories, office parks, and power plants. Another likely application is the monitoring of ecologically sensitive areas for fires, illegal logging, poaching, and other environmental threats such as invasive species.

Exploration, Aid Efforts, and Disaster Recovery: Drones and other robots could conduct searches to find lost vehicles or enter situations that are too difficult for humans.

Entertainment: Recreational drone flying is already a fairly established category in the toy industry. The quadricopter by Parrot was a trailblazer in developing technology that allows toys to be remote controlled by an iPhone. And one gyroscope-equipped helicopter manufactured by Syma places routinely among Amazon's top 20 best-selling toys.

Delivery and Errands: Drones could be deployed to deliver items such as prescription drugs from pharmacies, meals from restaurants, and food from supermarkets, as well as corporate documents. While not able to fly yet due to the FAA restriction, the "TacoCopter," designed in Silicon Valley, is already able to deliver tacos right to doorsteps in San Francisco via unmanned helicopter.

Logistics: Theoretically, large drones could travel between Amazon's warehouses (carrying heavier loads) for use in inventory management, rather than just final customer fulfillment.

continued on next page

Journalism, Filmmaking, and Photography: The possibilities for using drones in the realms of video journalism and documentary filmmaking are endless.

Farming: The Environmental Protection Agency is apparently already using drone technology to monitor livestock farms, and some farmers will likely eventually begin using drones to manage agricultural crops (see above).

Military: According to Peter W. Singer, a Brookings Institution drones expert, the military now has 8,000 UAVs in the air and 12,000 on the ground. The U.S. Air Force now trains more UAV operators than fighter and bomber pilots.

Source: Shortened and edited from Marcelo Ballve, "Commercial Drones are Becoming a Reality, with Huge Impacts for Many Industries," Business Insider, April 28, 2014.

Anderson stood up and drew a Venn diagram where "Empty Space" stood for geographic areas where drones could be kept away from people, "Data Hunger" stood for data opportunities, and "Money" for financial opportunity. He said 3DR's best opportunities exist at the nexus of "empty space, where there's lots of money, and a hunger for data."

Chang talked about "the future of *x*" as Anderson scribbled away: "once you let loose a bunch of hackers and the technology gets cheap enough, the hackers can go up from the bottom, burning man-style, figure out all sorts of little applications for themselves and that's where we take it all the way down to the bottom and it becomes a grassroots thing where hackers are creating all sorts of crazy uses." He added: "But what happens after, is that these use cases would give rise to commercially viable applications like agricultural assessment from the sky, geospatial mapping, or having one's own personal cinematographer five feet above all the time."

"I agree," said Anderson. "Big data[58] in areas such as agriculture, building inspection, and scientific research is definitely the opportunity. We are essentially data acquisition devices that are not miles in the sky, but three feet above that can go anywhere, anytime, at any resolution. And now we are going to figure out what to do with all this data." Anderson cited as an example Climate Corporation, a company that sold to Monsanto for $1.1 billion in 2013. Climate Corporation collected weather data via satellite and initially tried to sell them before discovering there was no market for these data. Instead, the company turned the data into a better weather insurance product for farmers.

Anderson believed that 3DR could help solve agriculture's big data problem because about half of the inputs in farming (fluids, pesticides, fungicides, and herbicides) were wasted since more was applied than needed or they were applied to the wrong places, such as the ground between plants rather than on the plants themselves. Agriculture was also the largest vertical that Anderson could "imagine today" because it was the largest industry in the world with the lowest regulatory barriers. Jensen added, however: "For agriculture, it's not about regulation or regular inspections, but it's more about increasing your yield, improving quality, or reducing cost to operate your farm."

Anderson's vision for farmers was to allow a farmer to buy a 3DR drone with a camera on board, set it up on the property, push a button on his/her smartphone, and have the drone fly around and scan crops to let the farmer know exactly where more/less water or pesticide was needed.[59] Drones would use high-resolution sensors to improve crop yield and decrease agricultural water and chemical use. Agricultural uses, however, would require modifications for longer flight times than standard use cases. Data were processed using specialized imaging software once drones returned.

The agriculture market also presented some obstacles. For instance, third-party agronomists typically provided crop data services. FAA regulations banning most commercial uses of UAVs precluded consultants from using drones, so the farmers themselves would need to use drones. But eventually, Anderson felt it made sense for 3DR to target consultants/crop analysts, not the farmers, after the FAA allowed for wider commercial use of drones.[60]

Jensen interrupted: "I don't think agriculture will necessarily dwarf all other markets, though. And neither will public safety. Inspection will be a potentially large market, at least in the short term. The point is that it's really hard to estimate the market sizes for this new area and the people who are doing the big studies are people who are repeating or applying what they see in military applications and that's not really relevant."

Jensen added: "Think of the inspection of wind turbines, bridges, buildings, oil and gas, power lines, and railroad tracks that all could be well-served by our products because many of these industries are highly regulated with regular high cost inspection requirements." In the case of wind turbines, companies needed to keep track of bird strikes. And companies were required to inspect the blades to make sure they were functioning properly for liability reasons. "Currently, they send people up and they repel down to inspect the blades, which is a pretty cumbersome process," said Jensen. "We could have our drone automatically inspect the turbines on a regular basis and could cover 100 in a day."

In building inspection, drones could help companies inspect cracks in buildings, for example, and for bridges, drones could create a 3-D map of a bridge every week and look for differences between those images that might be caused by settling or corrosion. In the case of power lines, instead of having a person inspect power lines for hot spots that could lead to power failure, drones could be used with an infrared camera. In the case of a factory, a drone could measure different types of gas emissions above smoke stacks.

Anderson said: "I agree with you on inspection, but I still think agriculture is going to be huge. And don't forget about the consumer markets such as personal aerial cinematography. You've got beautiful cameras, slow-mo, editing capabilities in Instagram, and now you can record your own life. It's not exactly cinema because you're not in a movie, but this is cinematic and you can apply Hollywood techniques to your own life. Filming could actually be our core business and we could build the creative tools of filmmaking into the platform."

Jensen said: "I agree, this is the number one application in consumer products for 3DR." He cited the fact that two-thirds of 3DR's drones sold with a stabilized gimbal, which keeps a camera steady during flight. "Anyone who is buying

this is likely using the drone for video production. And this doesn't even account for people who later put their own gimbal on there or a camera that isn't stabilized. My guess is that more than three-quarters of people are using our drones for video in the consumer market."

Anderson hoped that 3DR's drones could "get to the core of creativity." Prior to drones like these, people had only two, visual perspectives: eye-level and tens of thousands of feet from a plane. "That 100-foot perspective just wasn't available to us before and now it is," he said.

3DR's drones had a "Follow Me" mode where a user could use an app and press "Follow Me" and the drone would follow the user. The drone would position itself 30 feet behind the phone and 30 feet above and maintain a camera on the user as he/she walked. Anderson called this "the ultimate selfie."

As Chang sat and listened to Anderson and Jensen, however, he started thinking about how 3DR's had a "classic platform pioneer problem" where the company invents a space and purposely allows users to create use cases in order to grow the movement and acceptance of that platform, but once there is acceptance, competitors quickly jump in and "pick one area to focus on and can beat you if you don't focus," he said.

Chang jumped into the conversation: "The issue is that you can't do everything good at once so you eventually have to pick a few killer applications to focus on or you remain this platform provider and be out there for everyone to use in their own way, but you do have to pick a lane. It's possible to stay the platform provider if the market itself is growing fast enough that you are just going to sell more and more of that stuff anyway, but in markets like this where it is growing in spurts, what likely happens more is that you probably could take a few verticals and go deep on those as you try to monetize and strengthen the rest of the platform."

Jensen echoed Chang in that he believed 3DR was and would be, even more in the future, a platform company more than a product company, but he was less certain and wanted to wait and see what happens. "Part of what we're doing, is enabling a much larger ecosystem," he said. "We will be introducing over time, some really sophisticated software that will be able to gather and analyze data on the fly and we will also specifically write software for certain use cases that we think will be really lucrative."

He added: "But we will absolutely be thrilled when people write their own software or write software that they will sell to other people. In these cases, we can point people to our platform and to other partners and say, 'Go make a business out of this.' Or maybe we even license that software or maybe we don't. Maybe we send the systems to them at a discount and they go find all the bridge owners or inspectors in the world and sell it to them."

Jensen said that in the future, other companies could make apps with an application programming interface and software development capabilities for specific applications, like targeted pesticide spraying for agriculture, on top of 3DR's platform. In some cases, 3DR would work with customers/end users or service providers and in other cases in the future, "maybe we will even be the service provider if regulations are sorted out."

Jensen said that 3DR tried to stay "close to our customers and market trends" and at some point, the company had to make choices and in many cases, 3DR would be a market maker. "This is a hard exercise and part of what we do is look at the size of companies in a market, the size of a market as a whole, independent of our percentage of that. It's a bit of a shot in the dark, because there's not a lot that can be done ahead of working on a product that could really give you a great idea of potential markets because any outside information is not going to be great."

"Yes, I agree that it's a shot in the dark," said Chang. "Deciding which vertical(s) to pursue and which to do in partnership is the big question. Which do you pursue and which do you go double-down and build even deeper vertical solutions, or do you partner with specialists, consultants, and software companies who already serve the agricultural market and say, 'Here are all the tools, here's a platform of the software, you know your customer requirements, there's all the pieces you need to go create this new vertical solution for them.'"

The Future

As Anderson stood at the white board and thought about the similar, yet different views and options for 3DR, he felt a great sense of excitement and urgency. He marveled at the company and industry that had exploded in just a few years. By 2014, 3DR was selling tens of thousands of drones per year with revenue in the multi-millions and growing 100 percent over the past three years. He was also quite proud of the way that 3DR had launched and how it operated, with its open source community as its main innovation and organizational platform.

However, with competition heating up, he knew 3DR was at a critical inflection point. As Chang described 3DR's first mover advantage, he remained cautious about competitors: "The business part of 3DR was all accidental and while that's good, that also presents a danger too because if you're an accidental business, you're not quite as focused as one like DJI that comes in ruthless, honed on crushing a specific vertical or use case."

Anderson agreed, adding: "We built this company and compete with China but we are competing with what we thought China was 10 years ago. We anticipated software weaknesses, brand and marketing weakness, and channel-level weaknesses, but this new breed of competitors has none of these weaknesses—they are innovative, fast, they can do hardware and software, they do design, marketing, and they are global from the start. This is why we raised $37 million. We are competing with 21st century China."

Anderson pointed to how the propellers on a DJI Phantom were reverse threaded and spun on easily, tightening itself when the motor starts. "It's aerodynamically perfect and flexible," he said. "Everyone else screws their own on, but their way is a better experience." The Phantom also had its own built-in camera versus 3DR's IRIS, which used a GoPro-compatible camera. "Rather than taking a commodity camera and then building a relatively complicated mechanical apparatus around it, another possibility is integrating the camera into the drone," said Anderson. "For all our verticals, we are looking at extending the platform. While we love GoPro

and would like to work with them rather than compete with them, all our competitors are integrating the camera and doing it themselves."

Jensen, though, emphasized brand as a big driver in the industry since drones were very complicated products: "Being an early mover in this space and having the opportunity to build a great brand will also be defense mechanisms. We don't believe we need to own 100 percent of this market and we will focus on putting out a great product, building a great brand, and developing a great ecosystem with a great platform."

With competition to worry about, as well as which commercial vertical(s) to focus on, and the existing consumer market to grow, along with the platform issue, Anderson had his hands full. He, Jensen, and Chang, continued talking, playing with the IRIS and other competitor drones on the conference table as their voices echoed in the one-room high-ceilinged industrial office.

Notes

1. <www.wired.com/dangerroom/2012/06/ff_drones/all/>.
2. <www.trueventures.com/2012/11/05/welcoming-3d-robotics/>.
3. Versus a remote-controlled aircraft.
4. Anderson wrote *The Long Tail: Why the Future of Business is Selling Less of More* and *Makers: The New Industrial Revolution*, and was Editor-in-Chief of *Wired* from 2001 to 2012. Previously, he was at the *Economist* for seven years in London, Hong Kong, and New York in various positions, ranging from Technology Editor to U.S. Business Editor.
5. <www.trueventures.com/2012/11/05/welcoming-3d-robotics/>.
6. Federal Aviation Administration.
7. Marcelo Ballve, "Commercial Drones are Becoming a Reality, with Huge Impacts for Many Industries," *Business Insider*, April 28, 2014.
8. <www.washingtontimes.com/news/2012/jul/2/industry-offers-conduct-code-for-unmanned-aircraft/?page=all> and AUVSI Economic Report, 2013, p. 2. Andy Jensen, 3DR's CFO felt market data to be generally not helpful as explained further below.
9. <www.amazon.com/b?node=8037720011>.
10. Units range from individual autopilots to full vehicles. The blended average is around $200.
11. A bit (short for binary digit) is the smallest unit of data in a computer that has a binary value of 0 or 1.
12. <http://spectrum.ieee.org/aerospace/aviation/chris-andersons-expanding-drone-empire>.
13. Ibid., p. 65.
14. Ibid., pp. 9 and 63.
15. Ibid., 2012, p. 17.
16. Ibid., p. 73.
17. Ibid., p. 70.
18. <http://techshop.ws/>.
19. <http://makerfaire.com/makerfairehistory/>.
20. Anderson, op. cit., pp. 16 and 22.
21. Ibid., p. 74.
22. Ibid., p. 74.
23. Ibid., p. 74.
24. Anderson, op. cit., p. 128.
25. Ronald Coase was an economist who published a landmark article in 1937 called "The Nature of the Firm" that explained why companies exist (to minimize transaction costs).
26. Anderson, op. cit., p. 149.
27. Ibid.
28. Bill Joy, one of the founders of Sun Microsystems said: "No matter who you are, most of the smartest people work for someone else," which became known as Joy's Law.
29. Anderson, op. cit., p. 109.
30. Ibid., p. 196.

31. Anderson, op. cit., pp. 18, 66, and 88.
32. Nick Bilton and John Markoff, "A Hardware Renaissance in Silicon Valley," *The New York Times*, August 25, 2012.
33. Anderson, op. cit., p. 150.
34. Ibid., p. 158.
35. Ibid., p. 159.
36. <www.wired.com/dangerroom/2012/06/ff_drones/all/>.
37. Ibid.
38. Ibid.
39. Ibid.
40. Ibid.
41. Ibid.
42. Anderson, op. cit., p. 145.
43. <http://fusion.net/modern_life/story/jordi-muoz-drone-18219>.
44. <http://fusion.net/modern_life/story/jordi-muoz-drone-18219>.
45. Anderson, op. cit., p. 103.
46. <http://3drobotics.com/2014/01/chris-anderson-speaks-with-msnbc-about-the-drone-economy/>.
47. Anderson, op. cit., p. 117.
48. <http://spectrum.ieee.org/aerospace/aviation/chris-andersons-expanding-drone-empire>.
49. <www.wired.com/dangerroom/2012/06/ff_drones/all/>.
50. <www.wired.com/dangerroom/2012/06/ff_drones/all/>.
51. <www.cnbc.com/id/100731683>.
52. Anderson, op. cit., p. 227.
53. Acquired UAV company, Gatewing in 2012.
54. Parrot had a commercial product through its company SenseFly that it acquired in 2012 that sold for over $30,000.
55. Parrot was active in the consumer products market, but also invested in SenseFly, a commercial UAV company that was mostly on the sidelines.
56. <www.auvsi.org/home>.
57. Marcelo Ballve, "Commercial Drones are Becoming a Reality, with Huge Impacts for Many Industries," *Business Insider*, April 28, 2014.
58. 3DR has partnered with a big data company called Pix4D in Switzerland. 3DR collects data that are sent to Pix4D and packaged into maps.
59. Ben Popper, "How 3D Robotics is Building for America's Drone-Filled Future," *The Verge*, September 27, 2013.
60. For a longer discussion on what drones could be used for legally, see "No, You Can't Use a Drone to Spy on Your Sexy Neighbor," at <www.wired.com/dangerroom/2012/06/ff_dronerules/>.

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