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Platform Strategies of the Chinese Commercial Drone Manufacturer: A Theoretical and Empirical Study of Ecosystem Development

Jin Chen
Ritsumeikan University, Ibaraki, Osaka, Japan

From the perspective of the business ecosystem, this paper analyzes the competitive advantage and platform strategy of Da-Jiang Innovations Science and Technology Co., Ltd. (DJI), a Chinese commercial drone manufacturer that is currently leading the global commercial drone industry. DJI was established in 2006 and developed the industry's first core components such as drone control system. DJI released its "Phantom" in the United States in 2013 and occupied the global commercial drone market accounting for 70% in a short period of time. Its market share has maintained its superiority till present. During the inflection transition from the formation of a new ecosystem to expansion, DJI has defended and strengthened its core technology through a strong containment strategic action of competing with GoPro; therefore, DJI has obtained its hub position of multiple markets with bargaining power. In addition, DJI has entered the surrounding markets of corporate market from the general consumer market, and instilled its own product standards & design standards (reference design). Furthermore, it has stimulated and revitalized coexisting companies, individual & corporate customers for expanding the ecosystem of drone industry.

Keywords: business ecosystem, commercial drone, DJI, competitive advantage, platform strategy

Issues and Perspectives

Problem Presentation

From the perspective of business ecosystem, this paper analyzes the growth strategy of Da-Jiang Innovations Science and Technology Co., Ltd. (DJI), a Chinese commercial drone manufacturer that is currently leading global commercial drone industry.

Entering 21st century, along with the networking of information, the transformation of the industrial structure rapidly expands into the realm of non-digital industries, and companies in developed counties and emerging countries are developing the global industrial structure into a single business ecosystem. The studies so far has indicated that the platform firms are competitive for competitive in the new industrial environment (Gawer & Cusumano, 2002; Inoue, Maki, & Nagayama, 2011).

Established in 2006, DJI was the first company in the industry to develop its own core components such as drone control system. In 2013, the self-developed drone (Phantom) was introduced in the United States; in a short

Jin Chen, Ph.D., Professor, College of Business Administration of Ritsumeikan University, Ibaraki, Osaka, Japan.

period of time, it captured 70% of the global commercial drone market share, and had maintained its superiority to date (Figure 1).

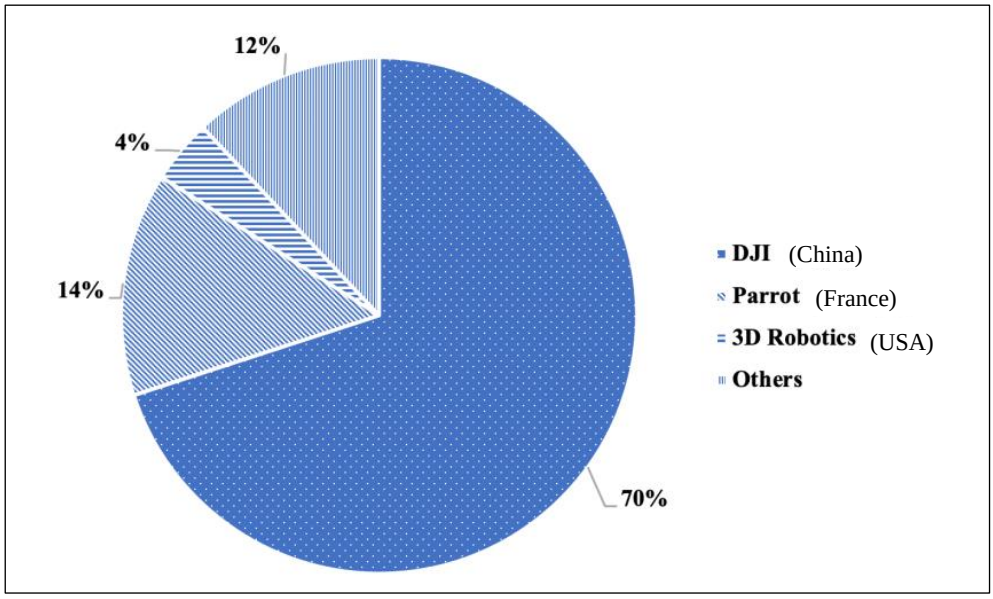

Figure 1. Global market units share of commercial drones (2014). Source: Japan Patent Office, 2019.

According to Drone Industry Insights, DJI accounted for 78.8% of the global commercial drone units share in 2019. At the same time, DJI's revenue grew from $26 million in 2012 to $1 billion in 2015 and $2.7 billion in 2018, while net profit had increased rapidly from $8 million in 2012 to $250 million in 2015 and $650 million in 2018. As of 2018, DJI's overseas market sales accounted for 80% of total sales, with the largest overseas market being North America and the second largest market being Europe (Luo, 2018).

Since 2015, DJI has released a wide range of products, including the small foldable (Mavic Pro), the even smaller (SPARK), the (AGRAS MG-1) for large-scale pesticide spraying, and the (M600) for professional large-scale aerial photography and industrial use; those models are active in every field of the world. DJI's products have already been widely applied in fields such as aerial photography, film production, agricultural production, property inspection, news reporting, firefighting, rescue operations, energy exploration, remote sensing mapping, and wild animal protection. Among them, DJI has set open standards and is developing a platform strategy while collaborating with coexisting companies and customer/user companies.

Based on above understanding, this paper focuses on how DJI has acquired a competitive advantage and built its platform from the perspective of the business ecosystem and how its platform strategy has developed. Then I would like to clarify the key research question.

Perspective

The business ecosystem is an analogy of the industrial structure of the ecosystem, and presents the overall collaborative relationship between companies in developing fields that are mainly forming the system of the information and communication industry. Like ecosystem in nature, business ecosystems are mix of companies with different roles. Iansiti and Levien (2004) claimed that there exist special firms that lead industrial evolution from a biological analogy. They called the company a keystone company and their corporate strategy a keystone strategy. In the field of competitive strategy theory, such a strategy is called a platform strategy.

A platform is a foundation that connects different elements or groups to build a network. A platform business is a business that provides infrastructure and rules that facilitate interactions among multiple different user groups by providing products (Maruyama, 2011). The platform of the IoT (Internet of Things) environment is a digital platform with a CPS (cyber physical system) structure. CPS is a mechanism that analyzes data taken from physical systems and such as things with a computing system (cyber) and feeds back the analysis results to the relevant system or other system. In the narrow sense, CPS is a technology that focuses on closed control feedback loops between embedded software controllers and devices to be controlled. It has been positioned as an important fundamental technology along with the progress of industrial softwarization and network (Takanashi, 2021).

The strategic actions of platform companies that influence the reaction behavior of coexisting companies and user companies are called strategic levers (Gawer & Cusumano, 2002). The platform strategy consists of a strategy for establishing an ecosystem and a strategy for expanding the ecosystem. The turn that connects the two strategies is called an inflection point. Whose turn (strategic lever) is the inflection point has a very important impact on the success or failure of each platform strategy (Tachimoto, 2017). Intellectual property management is very important in platform strategy, so when other companies try to enter the closed field, platform companies actively initiate patent disputes (Jackson, 1998). From the viewpoint of information flow, the source of the competitive advantage of positioning in a hub is pointed out as follows: (1) information access benefit and (2) information control benefit (Burt, 1997).

The creation of network externalities is an important mechanism for the success of digital platforms. It is necessary to provide a one-stop solution to the problems faced by users through understanding customer needs. Platform leaders encourage innovation among complimentary companies, and the more end-users buy platform-based end products, the more complementary product manufacturers will try to introduce more complementary products (Gawer & Cusumano, 2002). If you build a digital platform with a CPS structure, the data on the side of things will flow continuously and automatically, accelerating the growth speed. There are basically two types of competitive advantage: cost leadership and differentiation (Porter, 1985). Big data can be obtained by building multiple CPSs, and cost leadership and differentiation can be achieved at the same time by using it at almost zero cost.

Previous studies have revealed striking similarities in the industrial evolution of ecosystems. There are three elements that make up this similarity: platform companies, open and closed fields, and international division of labor between industries in developed countries and those in emerging countries. In the process of gaining a competitive advantage in the global ecosystem, platform companies (1) divide the system architecture into open fields and closed fields according to their own business models for international open standardization, and encourage the entry of industries from emerging countries into the open fields; (2) while positioning itself as a hub that mediates multiple markets, at the same time acquire competitiveness by "promoting open standards" and "development for emerging countries"; (3) stimulate and revitalize peripheral markets while strengthening bargaining power through "entry into peripheral markets", and maintain openness in division of labor networks through "reference designs" and "inter-company relationships with a simple and straightforward approach", to expand the ecosystem; (4) the rise of platform companies will cause a change in the international industrial structure. The transformation of the industrial structure is more likely to occur in coexisting company industries in emerging countries than in user company industries. Above effects can be expected (Tachimoto, 2017).

If we summarize the above theory in the analysis framework diagram (Figure 2), the platform strategy consists of the ecosystem establishment period, the transition period from the ecosystem establishment to expansion, and the ecosystem expansion period. At the time of ecosystem establishment, platform companies differentiate their system architectures into open and closed fields according to their own business models for international open standardization, and encourage the entry of industries from emerging countries into the open fields. In the period of transition from ecosystem establishment to ecosystem expansion, platform companies will win the turn "inflection point" that connects the two strategies, acquire the initiative in intellectual property, and be positioned as a hub that mediates multiple markets. During the period of ecosystem expansion, platform companies provide one-stop solutions to customer issues, strengthen their bargaining power by entering peripheral markets, stimulate and activate peripheral markets, and expand the ecosystem.

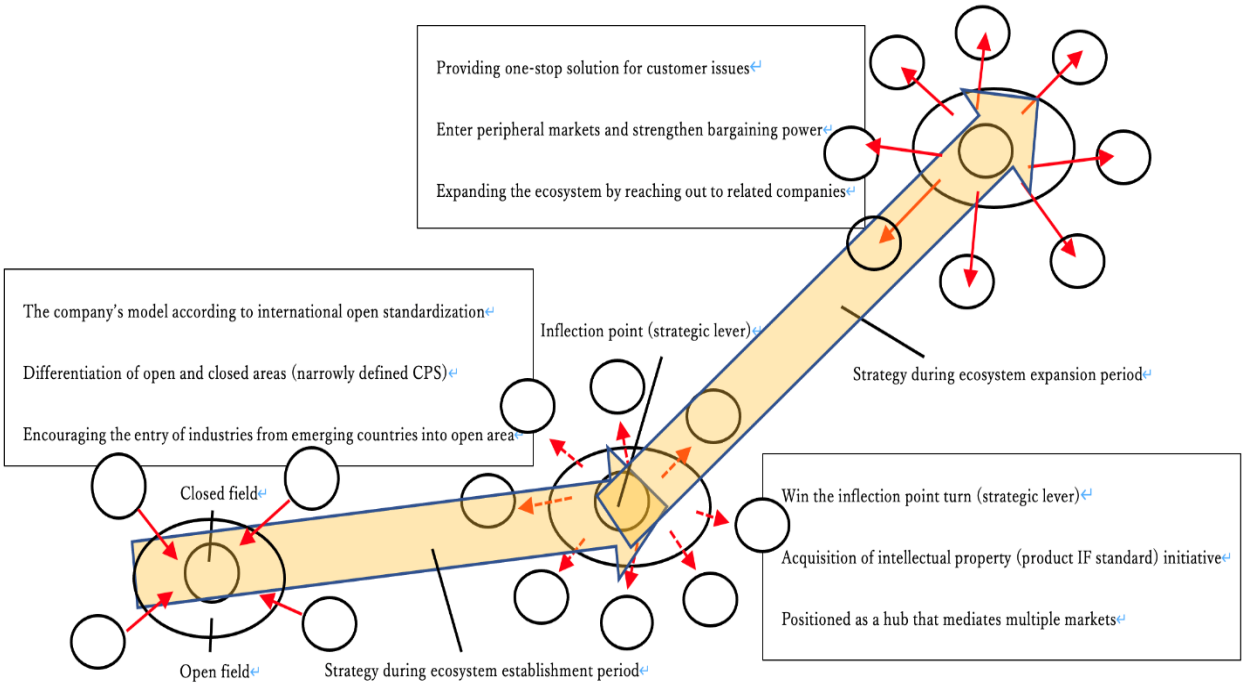

Figure 2. Analysis framework diagram: Competitive strategy of platform companies. Source: Created by the author.

However, until now, most of the research on platform strategies of manufacturing companies has focused on companies in developed countries. There is an analysis that the expansion of the market "industrial scale" in the open fields when the ecosystem expands provides growth opportunities for companies in emerging countries. But, we have not yet seen a case of researching companies in emerging countries as platform companies with a grasp of closed-fields technology. This paper aims to contribute theoretical research on the evolution of ecosystems in the manufacturing industry through the strategic analysis of DJI, a company in emerging countries and China that has grown to become such a platform company.

Next, regarding DJI's platform strategy, according to the analysis framework diagram above (Figure 2), Section 2 creates standards and establishes competitive advantages in the ecosystem establishment period, and Section 3 is platform construction and positioning as a market hub in the transition period from the ecosystem establishment to expansion. In Section 4, we will observe and analyze the development of the platform strategy in the ecosystem expansion period.

Creation of Standards and Establishment of Competitive Advantage

Utilization of Open Fields Technology and Founding of DJI

DJI is a commercial drone manufacturer founded in 2006 in Shenzhen, Guangdong Province, by Mr. Wang Tao (Frank Wang), who studied helicopter controllers at a university in Hong Kong when he was a student. Originally from Hangzhou City, Zhejiang Province, China, Mr. Wang has been fascinated by remote-controlled helicopter models and toys since childhood. In collage, he transferred from East China Normal University (Shanghai) to the Hong Kong University of Science and Technology in order to pursue his dream of controlling a helicopter (Economic Daily, 2015). There he met Professor Li Zexiang, who gave him a turning point in his life. Professor Li holds a Ph.D. in electronical engineering and computer science from the University of California, Berkeley, and is a robotics industry expert who also worked on AI (Artificial Intelligence) research at MIT. Professor Li has been a key person in the company's R&D since the establishment of DJI, and has also served as chairman of the corporation.

Mr. Wang had hoped to work in Professor Li's laboratory on a control system for automatic hovering of helicopters, but Professor Li's research field did not have this task. However, Professor Li supported Mr. Wang's research activities and added them on to his laboratory's approach agenda. Moreover, he made a team with two students and Mr. Wang for drone research, and had the university to raise 18,000 Hong Kong dollars for research expenses and inverted it. Professor Li fully supported the development of the drone control "closed field" technology that Mr. Wang wanted, using the "international open standardization" technology such as AI and robots that he had until then.

The "closed field" research that Mr. Wang focused on is the development of a control system that automatically keeps a drone model stationary in the air. In other words, it is a CPS technology that focuses on a closed control feedback loop between the embedded software controller and the device to be controlled. Mr. Wang later explained the technical principle as follows.

> By inertial measurement unit IU, sensors for measuring acceleration and angular velocity, GPS (Global Positioning System for positioning), electronic compass, we can obtain precise data on the drone's angle and velocity, and based on these data, can control the feedback driving of the drone pilot and make the drone automatically hover in the air. (Forbes Chinese Website, 2014)

The technology was later positioned as an important basic technology as the drone industry became more software-based and networked.

However, this research did not go well as planned while he was an undergraduate student, and the prototype that was the result of his graduation research ended in failure. In 2006, Mr. Wang entered the master s program at the same graduate school; at the same time, he founded DJI with two persons who were on the same research team during his undergraduate days in Shenzhen, Guangdong Province, while continuing to develop the control system for automatic hovering, and using "open source", he has also started a business that sells parts for helicopter-type drones that are outsourced to parts manufacturers around Shenzhen. In other words, while the "closed field" technology for helicopter-type drone control is being developed with the support of Professor Li at a graduate school in Hong Kong, the open field technology such as airframe and related parts is based on the international open standardization, and he made up his business model.

Development of Core Technology and Establishment of Competitive Advantage

Mr. Wang was unable to establish his own core technology for the first two years after establishing the

company, and the business did not take off easily. However, at the end of 2008, they succeeded in developing the helicopter control system "XP3.1", finally producing a great technology achievement.

Since 2009, DJI had revised its DIY (Do It Yourself) business method, in which customers had to look for parts and download programs by themselves; they adopted the bundling strategy (Nalebuff, 2004) of a so-called de-modularization, systemization, and turnkeyization, which provides a set of helicopter-type drone parts that are outsourced to parts manufacturers around Shenzhen and flight control devices developed in-house. At that time, in addition to DJI, small companies with a few employees were also developing the same business in the United Kingdom, Germany, and the United States, but DJI, which brought in the technology to hover automatically drones in the air, quickly achieved these sales. The company has overtaken these enterprises and already reached hundreds of thousands of RMB in 2010.

An important factor in DJI's rapid overtaking of other companies in the field is the convenience and cost advantage of procuring components located in Shenzhen. Shenzhen city has become the center of the electronics industry and the world's largest concentration of the consumer electronics industry, with the entry of many multinational companies from developed countries (Ding, 2013). In the past, among the Shenzhen consumer electronics industries, every time there was a major production boom for personal computers and mobile phones, the layers of supporting industries increased, leading to the rise of the drone industry, which relies on electronic components.

About this, the founder, Mr. Wang later said: "At that time, it was too expensive to start a company in Hong Kong. But Shenzhen was different. Shenzhen also had a very good industrial chain" (Entrepreneur Thinking Club, 2015). DJI has made full use of this industrial base, encouraged the entry of companies around Shenzhen into parts in the open field, and formed an ecosystem for the drone industry centered on Shenzhen.

Following the helicopter control system, in 2009 DJI developed a "three-axis inertial fixation aerial gimbal" for camera mounting on helicopter-type drones. This gimbal is composed of "a fixing device", "a transmission device", and "a camera device", and is a device that cancels out the vibration of the drone body using the principle of gyroscopic attitude control. Most of the image stabilization functions installed in digital cameras are electronic mechanisms, but because of the lag, if the drone vibrates, it will not be possible to maintain stable shooting. Therefore, Mr. Wang developed a more compact and lightweight aerial photography gimbal to realize more stable shooting for professionals, and provided the technology to a company related to the development of helicopter drones.

After that, in 2011, they developed a gyroscopic gimbal that can be used not only in small drones but also in various fields such as automobiles, steamships, and robots. The direct-drive gimbal developed by Mr. Wang can pursue stability, has a lower failure rate than traditional machine-driven gimbals, and extends the life of the gimbals by about six times compared to conventional products. In addition, they were able to achieve a lighter weight and reduce battery consumption.

In 2010, a DJI product distributer in New Zealand sold more than 200 gimbals (stabilizers for filmed video) for a helicopter-type control system that traded only a few dozen sets a month, and it is said that 95% of the gimbals were attached to a multicopter-type drone. This incident made Mr. Wang realize that the market size of multicopter-type drones has already far exceeded the market size of helicopter drones.

DJI immediately applied the helicopter control system technology to the multicopter-type drone and redeveloped it. Regarding the aircraft model of the multicopter-type drone, DJI used open information from MikroKopter, which was in Germany at that time, and outsourced the production of related parts to parts

companies around Shenzhen. In addition, DJI adopted the same bundling strategy for multicopter-type drones, following the conventional set sales of helicopter-type drone parts and flight control devices, and sold drone parts and control devices as a set. At that time, the multicopter market was still in its infancy, but DJI sold hundreds of sets a month, accounting for 70% of the market share (Heng, 2015).

Furthermore, since 2011, DJI has introduced new multicopter-type drone control system technologies such as the WooKong controller, Spreading Wings platform, Naza controller, and Flame Wheel platform. The company have established their superiority by developing and putting in on the market. In other words, DJI began to lead the creation of an interface (IF) standard for drones with a CPS structure and aerial imaging equipment while encouraging the participation of component manufacturers around Shenzhen. As a result, DJI began to break away from price competition and secure stable earnings by having a cost advantage in commercial drones and a high degree of consistency in finished products compared to other companies.

Platform Construction and Positioning as a Market Hub

Culmination of Aerial Photography Technology and Construction of Platform

DJI reached a turning point for rapid growth when it grasped new needs in the United States. In 2011, Mr. Wang set up an exhibition booth at an exhibition held in Indiana, USA, using his accumulated technology. At that time, Mr. Guinn[1], who was running an aerial film studio in the United States, was looking for a small drone that required stable filming. Therefore, Mr. Wang proposed to Mr. Guinn the self-developed direct-drive "gimbal", that is, the CPS technology of the drone + gimbal that automatically hovered in the air. With this as an opportunity, DJI began to expand into the United States, the world's largest aerial photography market, by adding a camera to its own drone + gimbal aerial photography technology (Mac, 2015).

After that, DJI saw a business opportunity and, through Mr. Guinn, partnered with Woodman Labs (renamed to GoPro from May 2014), which was called the "Digi-came (digital camera) revolutionary" in the field of consumer electronics in the United States at the time. The "GoPro" series developed by Woodman Labs was targeted at people who enjoy outdoor sports. In 2010, the company released its first high-definition wearable camera "Hero", and captured about 90% of the market share in the action camera field (Mac, 2015). A wearable camera is smaller and lighter than a normal video camera, so it can be attached to the body by attaching it to a helmet or a belt. It can also be attached to the handlebars of bicycles and motorcycles, the tip of surfboards, snowboards, etc., for shooting.

In addition, wearable cameras have an IP address assigned to the device itself and can be connected to the Internet by itself, so you can check the camera image from a remote location and save the recorded data via the Internet. In addition to viewing images, it is also possible to operate the camera from a smartphone, computer, tablet, etc., to change the shooting direction and zoom. These functions are technologies that transform video production into DX (digital transformation).

In August 2011, DJI set up a base in North America, targeting the consumer market. In January 2013, DJI developed a small drone "Phantom" with a gimbal product that can be attached to a GoPro camera, and released the first "flying camera" in the United States, the world's largest commercial drone camera market[2]. This product, which can be said to be the culmination of aerial photography, demonstrates the flexibility of combination,

[1] Colin Guinn, former head of DJI North America, later Chief Revenue Officer (CRO) of 3D Robotics.
[2] According to Inea Consulting (2014), the US commercial drone market accounted for 61% of the global market in 2013.

forming an excellent high-quality aerial imaging system with CPS structure through gimbal technology between the drone and wearable camera. In other words, DJI developed a completely new market need for "drone aerial photography" on top of the existing market needs for action cameras in the United States, and as a pioneer of this platform, the company gained the "first mover advantage" (Liberman & Montgomery, 1988) and began to grow rapidly.

IP management and Positioning in Market Hubs

In January 2013, DJI launched the "Phantom", a compact drone that can be equipped with a GoPro camera, and its sales have steadily expanded beyond its own drone products. However, troubles soon broke out between the two companies; DJI ended its partnership with GoPro in December 2013. The main reason for this is that Woodman Labs treated DJI as just an OEM (Original Equipment Manufacturer) for drones and gimbals (Heng, 2015; Mac, 2015). Woodman Labs wanted DJI to supply the drones and gimbals as "components", with most of the profits going to their own. On the other hand, Mr. Wang insisted, "We don't want to be another company's accessory. Among the finished products, GoPro's product is only the camera, so DJI, which provided the drones and gimbals, should take most of the profits". In the end, the two companies disagreed and the partnership was dissolved.

The dispute with GoPro was seen as a strategic action by DJI to protect its intellectual property, such as its drone control system and vibration-cancelling gimbals. Intellectual property management linked to business strategy is very effective for platform companies, because it is necessary to implement a strong containment strategy for a certain part of the ecosystem (Jackson, 1998). Both GoPro's wearable camera and DJI's gimbal have the role of compensating for the effects of vibrations on the ground and on the water surface, and shooting stable, high-quality images. However, most of the vibration compensation functions installed in wearable cameras are electronic mechanisms, but due to the delay, it is not possible to maintain stable shooting when the drone vibrates. This can be seen in the fact that most aerial drones have to use gimbals. In the midst of its conflict with GoPro, DJI has begun to strengthen these as core parts of high-quality aerial imaging systems in the nascent ecosystem, while strongly enclosing its own closed fields of drone control and gimbal technology.

Against this background, DJI dispelled the image that Chinese manufacturers did not have core technology until then, established and pursued strategic standards, and also promoted the development of wearable cameras. As a result, in 2014, the company released the camera-equipped drones "Phantom 2 Vision+", "Phantom 3", and "Inspire" developed in-house. Also, in July 2014, DJI developed a small hand-held gimbal "Ronin", and in October 2015, released a small gimbal "Osmo" with a camera, entered the camera business with the slogan "Change the common sense of cameras". The "Osmo" body weighs only 222 grams and is equipped with a technology called three-axis stabilization system, which could eliminate vibration and shaking and achieve stable, high-performance shooting. The camera installed in this product is a redesign of the "Inspire" camera for use with hand-held gimbals, which also makes it possible to install in-house cameras in small gimbals. In other words, DJI led the creation of the "Flying camera" IF standard, and began to grasp the core technology of wearable cameras following gimbals.

As a result, DJI's product "Inspire" ranked second in the US magazine Time's 2014 "Top 10 Tech Product Design" (Time, 2014). In addition, in the field of electronics for general consumers in 2015, among the "World's Top 10 Most Innovative Companies" selected by the US business magazine "Fast Company", DJI came in third, behind the Internet search giant Google and electric vehicle manufacturer Tesla Motors (Fast Company, 2015).

For the first time, DJI has adopted a strategy of bundling open-fields complements, with the "Phantom" camera-equipped drone, which launched in 2013, retailing for $679. Considering that drones at the time cost more than $1,000 even if consumers had to find the parts and assemble them by themselves, you can see how DJI has price competitiveness. "The product (Phantom) that we sold to beginners was also aimed at containing price competition with rivals", Mr. Wang later said (Mac, 2015). "Phantom" has high cost performance for both companies and consumers, and recorded amazing sales in the blink of an eye after its release. In addition to traditional corporate customers such as companies and research institutes, many of the purchasers are general consumers, and a new customer base has emerged and is expanding rapidly. As a result, DJI's sales in 2013 increased more than four times over the previous year. Additionally, DJI released the "Phantom 2 Vision+" in 2014 at a price of $1,200, which was also a hit. In 2014, DJI sold more than 400,000 drones, the majority of which were in the consumer "Phantom" series.

The battle between DJI and GoPro is at a time when the new ecosystem of drone aerial photography is shifting from establishment to expansion. DJI's drone aerial photography breaks through the limitations of traditional action camera land photography, utilizing features such as the drone's mid-air hovering and ultra-low-flying capabilities to expand the shooting range from flat to three-dimensional, and it is now possible to shoot subjects with greater detail from almost any angle. Judging from the results, DJI got a turn to connect the game of ecosystem establishment and the game of ecosystem expansion through strong enclosure strategy actions in the conflict with GoPro, so the company had built a digital platform with CPS structure including shooting, positioned itself at hubs in multiple markets, and gained bargaining power.

Development of Platform Strategy

Planting Standards and Entering Peripheral Markets

DJI utilizes the Internet to communicate smoothly with customers and user companies, while promoting its own products, technology, and corporate image, and spreading open standards. Since its establishment, it has sold to the Chinese domestic market and overseas markets such as the United States, Germany, Japan, the Netherlands, New Zealand, and Hong Kong through the Internet. Since then, the company has promoted globalization by establishing sales bases overseas, selling through both the Internet and distributors, and increasing the benefits obtained from its products and technologies while creating externalities.

Furthermore, DJI is thoroughly committed to providing a one-stop solution to the issues faced by users through understanding customer needs. DJI has posted multiple multimedia contents on its homepage "community" to intuitively convey the value of the product. These contents have the effect of making the customer aware of the product, and at the same time, greatly reducing the customer s "learning cost" by introducing how to use it. DJI also makes sure that all content can be spread to other mainstream social media, mainly on the homepage[3].

In the "knowledge base" provided to satisfy the customer's desire for knowledge, in addition to preparing the product firmware download page, manual videos such as product placement and assembly of each part are also uploaded to the site. DJI has also specified the safety education content in its "Safe Driving Guide", as well as providing information on "no-fly areas" around the world and regulators on drone flights around the world, making it easy for consumers to search. In this way, DJI instills its own product standards and design standards (reference designs) with consumers through the Internet, and strengthens the openness of its own standards.

[3] Currently, DJI handles social media such as Facebook, Twitter, YouTube, Vimeo, Instagram, Weibo, Youku, and WeChat.

DJI uses feedback data from general consumers such as photography experts and aeronautical model enthusiasts, and the company is diversifying consumer models from 10,000 JPY range models for beginners, including models that can shoot 360-degree shots by setting detailed settings such as the direction of the lens, with a built-in camera and high-definition image quality, supporting 4K images, all priced at 400,000 JPY for professional use[4].

DJI products have been purchased not only consumers, but also by many companies. For example, US regulatory agency records (as of July 13, 2015) show that 1,373 companies have applied for drone use, over 500 companies have been approved by the US government, and more than half of the companies carry DJI products (Popper, 2015). There is a lot of demand for DJI products from companies (businesses) as well, and DJI is reluctant to be seen as just a consumer drone manufacturer.

Therefore, DJI defines its own company as "a company that provides methods to create high-quality aerial imaging systems, and is also a platform company that provides drone platforms to various industries". In 2015, with a $75 million investment from Accel Partners, the company established a drone fund called SkyFund in Shenzhen to support developers of drone applications to further expand the drone ecosystem (36Kr, 2020).

As a pioneer in drones, DJI has far more CPS-structured flight and filming data than its competitors, and several times more open source products than its competitors. Taking advantage of this strength, DJI utilizes the SDK authentication method, i.e. opening the DJI-SDK to external developers[5]. In May 2018, DJI formed a partnership with Microsoft and released a software development kit for Windows 10, which has 700 million worldwide users. It also expanded commercial drone technology to the world's largest enterprise developer community by introducing Microsoft Azure and bringing DJI's vast data pool to a cloud-platform (Newsroom Press Release, 2018). External developers will build on DJI's flight and aerial photography capabilities, combine them with their own expertise, and apply them to their respective industries. Furthermore, in 2018, DJI established its own strategic investment fund to promote the ecosystem and began investing in developers, related product assemblers, distributors, and service providers (Economic Insights, 2018).

In March 2019, DJI began launching a new software tool "DJI Terra" that converts drone aerial data into digital 3D models and maps for easy analysis and decision making (Drone Media, 2019). DJI Terra (Figure 3) is easy-to-use mapping software that captures, analyzes, and visualizes data from the surrounding environment.

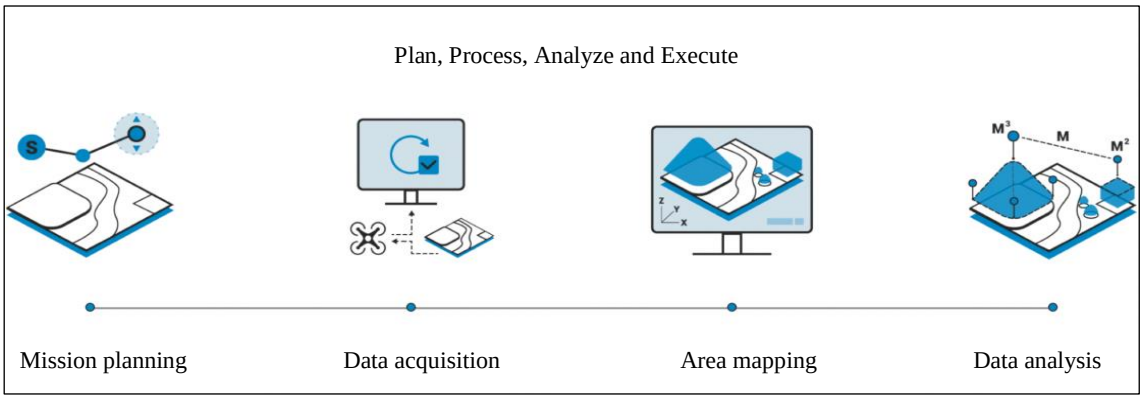

Figure 3. DJI Terra digitizes the world around it. Source: DJI, n.d.

[4] According to an article published in *Nihon Keizai Shimbun* on March 29, 2016.

[5] An SKD is a set of tools (including API libraries, sample programs, technical documentation, etc.) necessary for developing specific software. Abbreviation for software development kit, translated as software development kit in Japanese.

DJI Terra enables businesses and organizations employing DJI's drone technology to capture, visualize, and analyze aerial imagery in a wide range of applications, including public safety, construction, infrastructure, agriculture, and the film industry. It offers multiple mission planning types for drone pilots to plan autonomous flights based on the areas and objects they want to shoot, and the types of maps and 3D models they want to create. This will allow experts in each relevant industry sector to transform work-site examples into digital assets.

The hardware (drone) and software products, as well as flight and filming data and multimedia content information provided by DJI, will be "foundation for building a network by connecting different elements and groups" such as public safety, construction, infrastructure, agriculture, and film industries. Looking at a specific industry, for example, the construction industry, the products and information provided by DJI to industry stakeholders such as building owners, design firms, construction companies, and construction equipment manufacturers, are "an infrastructure and rules that encourage interaction for multiple different user groups".

Unlike consumer-oriented business, doing business with corporate customers requires not only technological superiority, but also the development of a dedicated team to provide meticulous service to customers in various industries. Since 2019, DJI had established its own vision of "becoming a technology company that continues to promote the progress of humankind", while improving management capabilities such as consolidating business processes and responsibilities/authorities, and the company began to actively challenge themselves to "enter peripheral markets" for corporate by building dedicated team (Nikkei Sangyo Shimbun, 2020a).

Since the beginning of 2019, DJI has been providing drone-based pesticide spraying and crop growth monitoring services to farmers in Heilongjiang Province in northern Chine and Xinjiang Uyghur Autonomous Region in western China. In relation to this, the total agricultural work area covered by DJI products has reached 330,000 square kilometers, which is about 90% of the land area of Japan, by mid-August 2020 (Nikkei Sangyo Shimbun, 2020b). DJI is also working with firefighting organization in Dalian City, Liaoning Province in the northeast and Chengdu City, Sichuan Province in the inland area to deploy drones on a trial basis at a rapid pace in order to use them to extinguish fires in high places such as the upper floors of buildings. In addition, in cooperation with JD.com (Jingdong Group), a major online shopping company, DJI has begun delivering products using drones, mainly in depopulated areas, and is conducting experiments overseas such as Indonesia, etc. (Nikkei Sangyo Shimbun, 2019).

At the end of March 2020, DJI formed a strategic alliance with Rosenbauer (Austria), a manufacturer of firefighting vehicles and firefighting equipment, to link software that grasps Rosenbauer's fire scene schematics and images taken by DJI with a drone (Nikkei Sangyo Shimbun, 2020c). In order to expand the sales of drones for industries in Japan, the company has partnered with Kubota (for agriculture), Komatsu (for mining), Microsoft Japan (for exterior wall surveys), Syngenta Japan (for pesticide spraying), etc., and reaches out to the field of renewable energy, also. In April 2020, the company partnered with West HD, a major solar power generation facility, and started a maintenance management business for solar power generation facilities using drones. There are about 8,300 DJI-certified drone pilots in Japan. In order to increase the number of skilled workers, the company will cooperate with West HD in school management (Nihon Keizai Shimbun, 2020a).

Encouragement of Related Companies and Expansion of the Ecosystem

As a platform company, DJI is frequently observed entering peripheral markets to gain bargaining power. As a pioneer of drone companies, DJI distributes its own product standards and design standards (reference designs) to component manufacturers, and while successfully matching and utilizing the component base around

Shenzhen, gaining more experience will enable bargaining power enhanced. For example, controller costs dropped from $2,000 in 2006 to $400 in 2011. Regarding Shenzhen's electronics industry, Mr. Wang said, "With the spread of smartphones, the cost of all electronic components such as accelerometers, gyroscopes, and GPS has dropped significantly. What was 5,000-6,000 RMB in the past is (2015) currently available for less than 100 RMB, which is more than expected" (Entrepreneur Thinking Club, 2015).

Regarding DJI's marketing strategy, Mr. Wang often described it as "aggressive"; Mr. Wang emphasized,

> Once we are in China, we must take advantage of China's excellent industrial chain. We first consider market share, and then profit. Quantity advantage dominates the market, and quantity advantage leads to cost advantage. We want to take advantage of our cost advantage to not only profit, but also gain more market share. (Forbes Chinese Website, 2014)

In other words, as a platform company, DJI places top priority on expanding its ecosystem by stimulating and activating peripheral markets while strengthening its bargaining power.

The drone industry centered around Shenzhen has developed greatly under the leadership of DJI. The supply chain consisting of domestic and foreign companies is complete, and the related ecosystem is expanding rapidly. Not only local companies, but also many Japanese, American, and European drone manufacturers have entered Shenzhen, and as of 2019, there are already about 400 drone manufacturers in Shenzhen, and their products are exported to more than 100 countries and regions around the world. Shenzhen has become the "World Drone Capital" both in name and readily. Additionally, these companies are leveraging drone technology to develop products such as self-driving cars, ships, and underwater robots (Shenzhen Special Zone News, 2019).

DJI is taking full advantage of the benefits of its ecosystem. In August 2020, Fomalhaut Techno Solutions (Tokyo, Koto), a specialized research company, examined the parts configuration of the latest model of DJI's drone, "Mavic Air 2", which is used for aerial photography, etc., and has a price of about 80,000 JPY in the diffusion zone (Nihon Keizai Shimbun, 2020d). As a result, the cost of parts price was estimated at $135, and the cost rate was 20%. It is said that for a Japanese manufacturer to make a drone with the same performance, it would cost twice as much as DJI's main unit price just for material costs, revealing DJI's high cost competitiveness. DJI's secret is repurposing open field components used in other products such as smartphones, etc. Of the approximately 230 types of parts, about 80% were using general parts on a monetary basis. For example, the camera used parts from high-end smartphones, and the GPS receiver was a part used in smartwatches. Only the battery and camera are expensive parts that cost more than $10. In addition to the cheapness, DJI is consistently striving to improve the integrity and quality of its products. "Mavic Air 2" can shoot 4K image quality in aerial photography, and has functions such as automatic tracking and obstacle avoidance. In order to achieve a light body weight of 570 grams, it has been designed to be equivalent to an electronic board. The software technology is also high, and the software is refined through trial and error by actively introducing new products.

These achievements have been supported by strengthening R&D capabilities. By 2015, DJI's R&D spending already accounted for about 7% of its revenue (Chen, 2015). As of 2018, about half of the approximately 14,000 DJI employees worldwide are engineers, of whom 20% are engaged in R&D (Luo, 2018). Many of executive and engineers are foreigners, and the nationalities of the employees come from more than 20 countries, including the United States, the United Kingdom, Germany, etc. In addition, they are working to establish research bases in Japan and overseas, and have hired former Apple senior engineer Rob Schlub, who has been involved in antenna design, and former Tesla senior engineer Darren Liccardo, who is working on the development of

autopilot system, and established a research institute in Silicon Valley, USA. Since then, DJI has continued produce R&D results one after another, and according to Patent Result, a patent research company, DJI has 185 valid patents for drones (Japan, as of January 2019), ranking top, more than three times of second positioned company[6].

In addition, DJI uses parts made by many companies in developed countries for product differentiation and quality improvement. Industrial drones have stricter requirements for weight reduction and reliability than those for general consumers. To meet that demand, DJI is increasing its procurement of parts from Japanese companies. For example, the "M600", a high-end-industrial drone, uses more than 50% of the parts made in Japan, such as sensors and lithium-ion secondary batteries. Industrial models are believed to be equipped with actuators and connectors made by Japanese manufacturers in order to ensure flight position accuracy, dust resistance, and high-capacity communication. For example, the US Boeing 787 has 35% Japanese parts, and DJI's industrial luxury drones surpass that percentage (Nikkan Kogyo Shimbun, 2016).

Looking at the parts configuration of DJI's latest model "Mavic Air 2" researched by the research company mentioned above, the storage device and camera are from Samsung Electronics (South Korea), and the memory is from SK Hynix (South Korea). It was confirmed that the IC (Integrated Circuit) for amplification and noise reduction was procured from Quarvo (USA), the IC chip that controls the battery was procured from Texas Instruments (USA), and the GPS was procured from Uprox (Switzerland).

In recent years, the U.S. military has begun to restrict the use of DJI products due to the conflict between the United States and China, and the Japan Coast Guard and other Japanese government ministries and agencies are also planning to review the use of Chinese drones (Yomiuri Shinbun, 2020). Since DJI's products use US-made parts such as ICs, some point out that if DJI becomes a new target in the future, it could cast a shadow over parts procurement (Nihon Keizai Shimbun, 2020b). In response to this, DJI has applied for establishment of its own factory in California, the United States, which will be the first drone assembly base outside of China, while commenting that "the decision to use the service is left to the user" (Nikkei Sangyo Shimbun, 2019). Furthermore, DJI emphasizes that even if the supply of parts from the US were to be banned, it would be able to supply the parts by itself (NNA Asia Economic News, 2019).

According to US research firm Frost & Sullivan, the global commercial drone market will surge from $3.7 billion to $103.7 billion in 2023, with China accounting for half of that[7]. Backed by huge domestic demand, DJI's sales strategy will likely place more emphasis on the Chinese market going forward. Currently, it has opened directly managed stores in various places of China and is conducting repeated trials in store assistant design and provision of interactive experiences[8]. At the same time, the company has strengthened their core technology by designing core components such as the CPU (central processing unit) that controls the motor driving the propeller of the drone in-house (Nikkei Business, 2018) and by acquiring Hasselblad, a Swedish high-end camera manufacturer (Tepper, 2017).

Conclusion

Based on the above facts and observations, the basic question of this paper is how DJI has acquired a competitive advantage and built a platform from the perspective of the business ecosystem, and how its platform

[6] According to an article in the morning edition of the *Nihon Keizai Shimbun* on August 29, 2020.
[7] According to the *Nikkei Sangyo Shinbun* article on April 30, 2020.
[8] According to the *Nikkei Sangyo Shinbun* article on March, 27, 2020.

strategy has developed. Based on the analysis framework shown in Figure 2, I have clarified the platform strategy by dividing it into the ecosystem establishment period, the transition period from the ecosystem establishment to expansion, and the ecosystem expansion period.

At the time of the establishment of the "drone aerial photography" ecosystem, DJI divided the system architecture into open and closed fields according to its own business model for international open standardization. Mr. Wang, the founder of the company, first used open information to sell parts for drones that were outsourced to parts manufacturers around Shenzhen as a set (bundling strategy) with a control device developed in-house. Furthermore, while utilizing standard technologies such as AI and robots that he learned at university, he continued to develop drone control system, filming gimbals, and closed-field CPS technology that combine these technologies with cameras. While promoting the entry of parts manufacturers around Shenzhen into open fields such as equipment and gimbal frameworks, he began to lead the creation of product interface (IF) standards.

In a time of transition from establishing a new ecosystem to expanding, DJI has made inroads into the North American market and developed a small drone with its own gimbal line that can mount a US GoPro camera. As a result, high-quality aerial imaging system with a CPS structure is formed between the drone and wearable camera through gimbal technology. And DJI developed the initiative of the product IF standard through the powerful enclosure strategy action of fighting with the US GoPro, and got the inflection point (strategic lever) of the ecosystem called "drone aerial photography". Closed field technology, that is, while protecting and strengthening the core part of the emerging ecosystem, completed a digital platform with a CPS structure that includes shooting, positioned itself as a hub in multiple markets, and acquired bargaining power.

During the period of ecosystem expansion, DJI entered peripheral markets, from consumer markets to corporate markets, through both the internet and distributors, and planted its own product standards and design standards (reference designs). The company understands customer needs, and strives to provide one-stop solution to the issues faced by users. At the same time, the company distributed its own product standards and design standards to component manufacturers, making good use of domestic and foreign component industries and accumulating more experience to strengthen its bargaining power. In addition, by leveraging the competitive advantage gained by positioning itself as a hub, they will release their vast amount of flight and aerial photography data to the corporate developer community, and form specialized teams to encourage innovation in corporations in various industries. And the company has the platform provide external resources according to their respective fields of expertise, stimulating and activating coexisting companies and user companies in the surrounding market, to further expand the ecosystem.

From the perspective of the business ecosystem, in the process of building the platform, DJI first created an interface (IF) standard for drones and gimbals, added a wearable camera, added a digital camera with a CPS structure that includes shooting, and created an aerial photography platform. Most of related parts are procured from manufacturers in Japan and overseas, and many parts used in other products such as smartphones and personal computers are also diverted. In addition, DJI is expanding a platform business that provides "the infrastructure and rules that facilitate the interaction of multiple different user groups" by providing products and information such as drones, flight and filming data, multimedia content, and mapping software, etc.

In the process of gaining a competitive advantage in the global ecosystem, DJI has competed by utilizing the domestic industrial base of emerging countries centering on Shenzhen, rather than the industrial base of developed countries from the beginning, unlike platform companies in developed countries. However, its industrial base was originally developed by the entry of many companies from developed countries due to the

globalization of the market, and the impact of the US-China confrontation seems unavoidable. In addition, if you observe the growth process of DJI, its technical base, development personnel, important parts, and other management resources are all closely related to developed countries, especially the United States. In anticipation of the expansion of domestic demand, DJI is shifting the center of gravity of the market to its own country, but the industry is watching with bated breath to see if the strong domestic demand will support it, or whether it will become a new source of division between the United States and China.

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