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Organizing Form, Experimentation, and Performance: Innovation in the Nascent Civilian Drone Industry

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Abstract. Our aim is to explore whether the benefits to firms of using community-based innovation extend to *nascent markets*: uncertain, high-velocity settings with novel, often complex products. Grounded in a rare empirical comparison, we closely track the two ventures (one using community-based innovation and the other firm-based) that pioneered the na2scent civilian drone market. We unpack how each addressed the three major innovations that shaped this setting. Our primary insight is that the firm organizing form for innovation performs best relative to communities in nascent markets. Firms have a *coordination advantage* that enables quickly and accurately targeting experimentation and problem-solving processes to reduce the many specific uncertainties that characterize these markets. Although communities can help, their task *self-selection advantage* works best in stable settings such as established markets with simple products (e.g., modular software) and in ambiguous settings in which low-cost randomness pays off. Broadly, we contribute a theoretical framework that identifies how organizing form and problem type *jointly* shape innovation performance. Most important, *uncertainty* forms a boundary condition for when firms should rely on firm-based (versus community-based) organizing for innovation.

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Keywords: organizing form • experimentation • nascent markets • innovation • communities

Innovation is at the heart of why some firms succeed in nascent markets and others do not. *Nascent markets* are those that are new and evolving (Santos and Eisenhardt 2009, Navis and Glynn 2010). Here, solving a complex technical problem (Furr 2019), designing a unique business model (McDonald and Eisenhardt 2020), and developing a novel product that fits the market (Zuzul and Tripsas 2020) are among the innovation challenges that are crucial to success. For example, firms that solved successive industry-wide innovation problems in the nascent residential solar market in the United States succeeded, and others did not (Hannah and Eisenhardt 2018).

Recent research on open innovation suggests that firms can leverage communities to solve innovation problems (Lakhani et al. 2013, Alexy et al. 2017). Consistent with this research, we define *communities* as organizations composed of actors working with each other and freely sharing knowledge related to a common interest (O'Mahony 2003, Lakhani 2016). Compared with the firm organizing form (Puranam et al. 2014),[1] the community form is characterized by open (versus closed) membership boundaries, self-selection into tasks (versus assignment by managers), open (versus proprietary) knowledge, and primarily intrinsic (versus extrinsic) incentives, such as social good and personal learning.

Although communities share these common elements of organizing form, the specific nature of work varies. Some are user communities that form to share knowledge about a general area of interest, such as juvenile products (Shah and Tripsas 2007). Others are open-source communities that form to collaborate around particular products, such as the Linux community (Raymond, 1999, Nagle 2018a), or to crowdsource solutions, such as OpenIDEO (Lifshitz-Assaf 2018, Lakhani et al. 2020). Firms, in turn, can leverage communities. For example, entrepreneurs who emerge from communities may work with these communities to gain product feedback (Shah and Tripsas 2007, O'Mahony and Lakhani 2011). Firms may develop relationships with communities by which they learn new skills and contribute to collective product innovation (Nagle 2018a), such as when firms adopt Linux and work with its community. Firms may also use communities to crowdsource solutions to improve their own products (Poetz and Schreier 2012, Piezunka and Dahlander 2019). For example, LEGO relies on the Adult Fans of Lego community for much of its product innovation (Lakhani et al. 2013).

Prior theoretical work suggests that the community organizing form may be more effective than the firm one for solving innovation problems for several reasons. First, communities have *lower costs*—that is, they are less expensive than internal R&D (Altman et al. 2015, Alexy et al. 2017). Although some governance may be required (Dahlander and Wallin 2006, O'Mahony and Bechky 2008), it is unnecessary to incentivize members with financial rewards like those employees receive (von Krogh et al. 2012). Consequently, communities can harness the contributions of potentially thousands of members with relatively little regard for internal resource constraints (Raymond 1999, Benkler 2002, Lerner and Tirole 2002).

Second, communities have the advantage of *individual experimentation*—that is, inexpensive, diverse, and large-scale exploration by individual members as they experiment to learn about and engage in self-identified tasks. This self-selection into tasks allows members to explore their own interests along their multiple chosen paths (Baldwin and Clark 2006, Faraj et al. 2011). Because members freely exchange their knowledge without IP restrictions, members also can learn from the exploration of others. Further, because communities typically allow anyone to join, they often are large and diverse, and so able to explore the knowledge landscape broadly (Felin and Zenger, 2014). In contrast, many firms lack the diversity of employees and the scale to explore broadly, especially beyond their expertise.

Third, communities can be more *flexible* than firms. By flexibility, we mean the ability to reconfigure quickly and adjust to new circumstances (e.g., Zuzul and Tripsas 2020). Unlike firms, communities have few if any bureaucratic impediments to project approval and implementation, and so innovation can advance unimpeded (Fjeldstad et al. 2012, Felin and Powell 2016). So, although firms may have a coordination advantage, including formal authority to hire employees and organize their efforts, communities have a self-selection advantage. That is, members have the autonomy to work on problems they deem relevant. Thus, communities can easily reconfigure themselves and adjust to innovation problems as they arise (Fjeldstad et al. 2012, Felin and Powell 2016).

Finally, communities are particularly effective for *modular problem solving* (Baldwin and von Hippel 2011)—that is, decomposing problems into discrete pieces that can be solved independently (Baldwin and Clark 2000). Because members self-select tasks and act independently, they can work in parallel with little direction. Also, because members select the pieces that interest them, they are more likely to participate and be motivated (Shah 2006). When communities are large and diverse, the form is particularly fast and effective at modular problem solving (Baldwin and von Hippel 2011). Finally, although the effectiveness of modular problem solving is limited to problems that are nearly decomposable (i.e., simple, not complex) (Baldwin and Clark 2000), recent technologies are transforming some complex problems into nearly decomposable ones, thus making modular problem solving more applicable (Baldwin and von Hippel 2011).

In sum, there is an emerging view that the community organizing form is cheaper, better suited to broad exploration, more flexible, and better able to use modular problem solving to solve a variety of innovation problems than the firm form. For some, the implication is that we are in the midst of a paradigm shift from firm- to community-based innovation (Baldwin and von Hippel 2011, Gulati et al. 2012, Altman et al. 2015).

Yet, although the innovation potential of communities is compelling, research leaves open whether these benefits for firms that rely on communities for innovation extend to nascent markets (our focal interest). There are several reasons. First, it remains unclear whether communities can effectively navigate the specific challenges associated with the uncertainty of nascent markets (e.g., Rindova and Kotha 2001, Eisenhardt and Bingham 2017, Furr and Eisenhardt 2021). Following Davis et al. (2009), we define *uncertainty* as the lack of predictability about what will happen. Specifically, nascent markets are characterized by unpredictable or contested product definitions (Hargadon and Douglas 2001, Anthony et al. 2016), uncertain product–market fit (Hiatt and Carlos 2019, McDonald and Gao 2019), and lack of a dominant design or legitimated category (Santos and Eisenhardt 2009, Navis and Glynn 2010). Thus, innovation in nascent markets often focuses on rapidly resolving specific knowledge uncertainties (Katila and Chen 2008, Gans et al. 2019, McDonald and Eisenhardt 2020) rather than broadly exploring for ambiguous knowledge in unknown locations.

Second, although research indicates that modular problem solving by communities works well for certain or nearly decomposable (i.e., simple) problems (Baldwin and von Hippel 2011), it does not address solving the novel (i.e., uncertain), complex (i.e., many, many interrelated components) problems that often occur in nascent markets (e.g., Hannah and Eisenhardt 2018, Ott and Eisenhardt 2020). Finally, although research offers empirical evidence for the effectiveness of community-based innovation, the comparative literature on organizing form is mostly theoretical (e.g., Baldwin and von Hippel 2011, Felin and Zenger 2014, Altman et al. 2015). So there is little (if any) systematic empirical evidence comparing the benefits of firm- versus community-based organizing forms.

Overall, although innovation is essential in nascent markets, and the innovation potential of communities and the benefits that accrue to firms using them are convincing, it is unclear whether these benefits extend to firms relying on communities for innovation in nascent markets. We address this gap. Thus, we ask the following: how does organizing form (i.e., firm- and community-based organization of innovation) influence innovation performance of firms in nascent markets?

Given limited theory about organizing form in nascent markets and little comparative empirical evidence, we use multicase theory building (e.g., Eisenhardt and Graebner 2007) to compare two for-profit ventures: DJI (FIRM) and 3DR (COMM).[2] These ventures have many similarities, such as founding team, funding, and products. Yet they adopt strikingly different organizing forms for innovation. FIRM uses the firm-based form. This venture hired, paid, and directed the tasks of employees to develop proprietary product innovations. In contrast, COMM relies on the community organizing form. The members of an open-source, user community chose and developed product innovations that COMM manufactured and sold back primarily to the community. Using in-depth interviews and archival data, we closely track how each venture tackles major industry innovations. A key strength of our study is that these innovations vary along relevant dimensions from prior research (i.e., uncertainty, complexity, ambiguity), thus enhancing our scope and generalizability. Overall, COMM and FIRM offer a clear comparison of organizing form across the three major innovations that shaped the nascent civilian drone industry.

We contribute to the literature on comparative organizing form (e.g., Afuah and Tucci 2012, Felin and Zenger 2014, Puranam et al. 2014) and innovation in nascent markets (e.g., Furr 2019, Brown and Eisenhardt 1997, Zuzul and Tripsas 2020). Our primary theoretical insight is that the firm organizing form performs best relative to the community form for firms in nascent markets—that is, uncertain, often high-velocity settings with novel, frequently complex products. Specifically, the firm organizing form has a *coordination advantage* that enables quickly and accurately targeting experimentation and problem-solving processes toward reducing the many specific uncertainties that characterize nascent markets. In contrast, although communities can be helpful in nascent markets, the task *self-selection* advantage of communities works best in stable settings such as established markets with simple (i.e., nearly decomposable) products, such as Wikipedia, snowboards, and modular software, and in ambiguous settings in which low-cost randomness pays off. In sum, although there is an emerging view of a paradigm shift from firm- to community-based innovation, we contribute that the firm is often the better organizing form for innovation in nascent markets.

Broadly, we also contribute a theoretical framework for how organizing form and problem type *jointly* shape innovation performance. Prior comparative work centers on problem solving and articulates two dichotomies: ambiguous (versus certain) knowledge and simple (versus complex) problems (e.g., Afuah and Tucci 2012, Felin and Zenger 2014). By focusing on nascent markets, we contribute to the theoretical comparison of organizing forms by (1) adding *problem finding* (not just problem solving) and (2) expanding the *repertoire of innovation processes* that address uncertainty well. These include hybrid and integrative problem solving as well as parallel and serial experimentation. Most importantly, we crystallize that uncertainty is a boundary condition for when firms should prefer firm-based (versus community-based) organizing for their innovation.

Methods

We address our research question with a multicase, theory-building approach that also fits our process research question (e.g., DiBenigno and Kellogg 2014, Anthony et al. 2016, Eisenhardt 2021). Multiple cases are effective because their replication logic across cases typically produces more robust, parsimonious, and generalizable theory than single cases (Eisenhardt and Graebner 2007). We also use an embedded design with multiple units of analysis (i.e., innovations, ventures) (Yin 2009). This design (described later) improves richness and accuracy by examining three innovations by two ventures, thus grounding the emergent theory in six case observations.

Research Setting

We began with an interest in experimentation. While searching for a setting, we had a chance encounter with a civilian drone executive who explained that his industry would be ideal. Experimentation is essential and widespread because drones integrate multiple technologies and components into an overall product design. So innovation occurs in components and at the system level where complexities such as magnetic interference are relevant. We soon recognized an even richer opportunity to study the two civilian drone ventures that pioneered the industry. These ventures have many similarities but strikingly different organizing forms for innovation. As is acceptable in multicase theory building (Eisenhardt 1989a) and broadly grounded theorizing (Glaser and Strauss 1967), we then shifted our research question to study the implications of organizing form for successful innovation in nascent markets.

Sample Firms

COMM and FIRM are two ventures that began as the civilian drone industry emerged in 2007.[3] Studying ventures has advantages. First, ventures are often the primary actors at the start of an industry, thus fitting our interest in nascent markets. Second, because ventures are small, they provide more transparency into organizing form than large firms. Finally, because ventures are young, we can track them from their beginning and so limit left-censoring.

The founders of both ventures were drone hobbyists. Chris Anderson, primary founder of COMM, was a physicist and journalist. He started building drones as a backyard project. FIRM's primary founder, Frank Wang, began tinkering with radio-controlled (RC) helicopters in high school and started FIRM after graduating from the Hong Kong University of Science and Technology (HKUST). The initial product for both was a flight controller: a hardware–software product that makes drone flying easier (like an automatic transmission makes driving a car easier).

Anderson launched an open-source user community for drone hobbyists, DIY Drones, in 2007. Consistent with the definition of communities (O'Mahony 2003), DIY Drones consisted of individuals drawn together around a common interest (i.e., making and flying hobbyist drones). Anyone could join, members self-selected tasks, no one was paid, and knowledge was freely exchanged and open source. About a year later, Anderson and a member started COMM as a for-profit venture to manufacture the open-source hardware components designed by community members. COMM primarily sold these products back to the community. As COMM's goals evolved, its relationship with the community also changed (described later). This offers a unique window into the implications of this evolving relationship. Frank Wang launched FIRM with two other engineers after they graduated from HKUST and began to work full time in 2007. They started FIRM as a for-profit venture to design and manufacture proprietary hardware and software for drone hobbyists.

The key difference that we explore is how innovation occurred in each. Although COMM was a for-profit venture, it organized its innovation with the community form. Anderson believed that communities with their open-source values would create more, more diverse, and cheaper innovations than firm-based innovation (Anderson 2012). The rest of COMM was organized as a firm: the founding team consisted of Anderson (CEO) and a manufacturing cofounder. They hired, directed, and paid employees (initially in manufacturing). FIRM was also a for-profit venture but organized the entire firm (including innovation) using the firm form. Consistent with the firm form, these executives hired employees, assigned their tasks, paid them, and patented FIRM's IP. Although some employees were aware of DIY Drones, FIRM employees did not actively engage in this or any community (including as employees on FIRM's behalf) during our study. Instead, FIRM focused on its own cutting-edge innovations and actively patented them using a premier U.S. law firm. The founding team consisted of Wang (CEO and CTO) and two technical cofounders. Later, both ventures added functional areas and executives.

COMM and FIRM share many similarities. Both began about the same time. Their founding teams were small and comprised hobbyists with tech backgrounds. They were also first-time entrepreneurs without industry experience. Thus, neither fits the description of the founding teams of high-performing ventures (e.g., Eisenhardt and Schoonhoven 1990, Chatterji 2009, Eesley et al. 2016a). Both began with a similar initial product (i.e., flight controller) and product meaning (i.e., make drone flying easier) for a similar buyer (i.e., drone hobbyists). Their goals were similar. Both sought to build modest, self-sustaining businesses and relied on friends-and-family funding. Later, both saw the same major opportunity of the mass market, shifted their goals to become significant enterprises, and received similarly large investments from leading VCs, including Silicon Valley. A key strength of our study is that these many similarities mitigate plausible alternative explanations that are not of theoretical interest (Table 1).

Data Collection

We use several data sources: (1) archival material, including news media, corporate, and community sources in English and Chinese; (2) interviews with executives, engineers, and investors at each venture and with community members, including core (i.e., most actively engaged) members; (3) interviews with other informed sources, such as industry experts, users, and rivals; (4) on-site observation; and (5) informal emails and phone calls to clarify details. Such varied data sources provide triangulation among sources and improve accuracy (Eisenhardt 1989a, O'Mahony and Bechky 2008). Table 2 summarizes.

We gathered archival data using Google, Crunchbase, LexisNexis, and Factiva covering our study period. We also worked with two native Chinese speakers to access Baidu, collect similar archival materials from Chinese-language sources, and translate them. The first author read all media accounts for each venture from inception. We supplemented these data with company data (e.g., press releases), community websites (e.g., blog posts), teaching cases, and books by executives. We continued archival data collection throughout the study. Because many news articles simply mention the venture (e.g., COMM as an

Table 1. Focal Ventures

	COMM	FIRM
Primary founder	Chris Anderson	Frank Wang
Age	46	23
Education	BS, physics	BS, electrical engineering
Industry experience	None – Journalist	None – Student
Entrepreneur experience	None	None
Co-founders (Function)	One young (early 20s) inexperienced engineer (manufacturing)	Two young (early 20s) inexperienced engineers (engineering)
Organizing form	Community for innovation, Firm for remaining activities	Firm
Primary location	Northern California	Shenzhen, China
Initial goals	Modest, self-sustaining business	Modest, self-sustaining business
Initial funding	Friends & family	Friends & family
Initial product (Meaning)	Flight controller (airplane) (Make drone flying easier)	Flight controller (helicopter) (Make drone flying easier)
Initial customer	Global drone hobbyists, esp DIY Drones community	Chinese drone hobbyists
Later goals	Significant global enterprise	Significant global enterprise
Later team	CEO + heads of finance, marketing, manufacturing, community, and later engineering	CEO + heads of finance, marketing, manufacturing, and engineering
Later funding	$5M series A (2012) & $30M Series B (2013), including Silicon Valley VCs	$1M Series A (2012) & $30M Series B (2014), including Silicon Valley VCs

industry participant), we distinguish these from focal articles that are about the venture (or perhaps another firm) and at least 750 English words. Focal articles typically cover recent events such as product launches and discuss venture actions, strategy, and history. The first author read all employee reviews (Glassdoor, Kanzhun) and press releases as well as a random sample of all community blog posts/message boards and a deliberate sample of those on the focal innovations. Both authors read all teaching cases and focal articles.

We gathered 118 interviews with internal and external informants. We conducted 58 semistructured interviews in three waves with internal informants—that is, executives, engineers, and investors at each venture plus community members.[4] We supplemented these interviews with 32 online interviews with internal informants. We conducted 28 interviews with external informants, such as industry experts, rivals, and users to add perspective. These triangulated data from multiple relevant perspectives and times provide a rich and more reliable understanding of innovation processes (Fayard et al. 2017).

We conducted internal and external interviews in three waves. These interviews lasted one to two hours and were recorded and transcribed. The first wave was Q3 2013–Q1 2014. We followed with a second wave (Q3 2014–Q1 2015). A smaller third wave in 2017 (Q1–2) was especially useful for filling gaps. Thus, we combined real-time (more accurate) and retrospective (more efficient) interview data and so enhanced both external and internal validity by increasing the observations upon which to ground our emergent theory.

We used a semistructured interview guide. First, we asked informants to describe their role. Second, we asked them to provide a chronological account of the focal venture's history (since founding or the prior interview). For external informants and community members, we adjusted to fit their knowledge, such as industry (experts) and community actions (members). We used interview techniques, such as nondirective questioning and courtroom-style emphasis on facts and actions to gather open-ended narratives and minimize response bias (Eisenhardt and Graebner 2007). We gave anonymity to encourage candor and supplemented these interviews with all available online interviews. All interviews were recorded and transcribed. The result is chronological narratives including events, decisions (e.g., product architecture choice), activities (e.g., experimentation), and actions taken by the informant and others from the perspective of the informant. Collectively, these narratives provide a holistic view of the venture history and information from multiple perspectives, including about specific innovations and innovation processes.

Data Analysis

Following theory-building from multiple case methods (Eisenhardt and Graebner 2007), we began by preparing case histories for each venture. The archival data (especially focal articles) were particularly useful to build an initial timeline and later to corroborate events, activities, actions, decisions, and performance. The interview data were particularly useful for fleshing out timelines and providing rich process details unavailable in the archival data (e.g., activities such as

Table 2. Major Data Sources

		COMM		FIRM	
Source	Primary purposes	Quantity	Details	Quantity	Details
Internal interviews	Firm history, innovation and other processes, actions, decisions, mistakes, and info not in archival data	35	Four executives Four engineers 14 community members (six core) One investor	23	Three executives Three engineers Two investors
Internal online interviews	Same as internal interviews	21	Three executives, Two employees For example, YouTube, CommercialDrones.fm	11	Two executives, One employee For example, YouTube, CommercialDrones.fm
External interviews	Same as internal interviews, industry history	12	Two rivals Four industry experts Four users	16	Two rivals Four industry experts Six users
News media articles Focal (total)	Triangulate events such as launches and funding, actions, performance, and miscellaneous info, initial timeline	35 (390)	*Forbes*, *The Wall Street Journal*, *Wired*, etc.	21 (800)	*China Daily*, *Forbes*, *Reuters*, *The Wall Street Journal*, etc.
Company press releases	Triangulate data on products, hiring, funding, and other events, initial timeline	58	Company website	219	Company website
Employee reviews	Triangulate data on organizing form, culture, and processes	28	Glassdoor.com	153	Kanzhun.com
Teaching cases (Focused on venture)	Triangulate data on products, dates, structure and processes, industry history	3 (1)	Harvard Business School Publishing: UC Berkeley, HBS	4 (2)	Harvard Business School Publishing: HKUST, HBS
Community blogs and message boards	Personal drone activities, queries, miscellaneous info, info on focal innovations	900+	DIY Drones	*None*	N/A
Books	Triangulate data on organizing form and processes, background into	2	For example, Makers: The New Industrial Revolution	*None*	N/A

experimentation, mistakes, reasons for decisions, conflicts, and alternatives considered but not pursued). These data were essential to understand innovation at each venture. The five teaching cases (three on the focal ventures, two on other firms) were primarily useful for industry history, timelines such as product introductions, and details about organizational structures (e.g., reporting relationships) and processes (e.g., hiring). The archival community data were mostly unrelated to the innovation process (e.g., members' weekend drone activity), but they (especially blogs about focal innovations) occasionally sharpened the timeline and triangulated with other sources. One author wrote initial case drafts, and the other reviewed the data to form an independent view. We resolved the few discrepancies by returning to the data or occasionally to informants. The result is case histories of about 80 single-spaced pages for each venture.

Within-Case Analysis. We analyzed each venture case broadly and in relation to our research question. Early on, we realized that we could improve the analysis with an embedded design (Eisenhardt 1989a, Yin 2009)—that is, analyze how each venture addressed the three major industry-wide innovations during our study (i.e., six venture-innovation cases). Consistent

Table 3. Three Major Industry Innovations

	Quadrotor product architecture	Drone gimbal	RTF drone
Problem finding	Ambiguous	Uncertain	Certain (i.e., obvious)
Strategic Problem	Flawed product architectures (dominant design)	No killer application Later, low-quality video (product–market fit)	Assembly hassle (product–market fit)
Problem solving	Simple	Moderately complex Uncertain	Complex Uncertain
New product	Quadrotor drone	"Flying camera"	Mass market product
New customer	Broad range of hobbyists	Professional users	Commercial and consumer users
Subsequent industry growth	About 10× in 2010	102% in 2012	136% in 2013
Representative quote	"Moving to the quadrotor was an unbelievably, extremely important decision." (industry expert)	"The gimbal … that's where the key innovation is." (industry expert)	"FIRM reinvented the industry." (industry expert)
Innovator	**COMM**	**FIRM**	**FIRM**

with others (Edwards and Gordon 1984, Katila and Shane 2005), we defined *innovation* as the invention and commercialization of new products or services. Later, we saw the importance of problem finding—that is, the process of identifying a dilemma or problem to be solved (Katila 2002, Baer et al. 2013). For example, we saw that faster and more accurate problem finding gave FIRM a head start in solving the gimbal problem that yielded later advantages such as a favorable brand and low costs. Thus, we expanded our conceptualization of innovation to include problem finding.

We study the three major industry-wide innovations that were the significant industry inflection points during our study. Specifically, each (1) was a technical advance that resulted in a qualitatively different civilian drone product and customer set; (2) shifted the revenue trajectory of the civilian drone industry and innovating firm upward; (3) addressed a well-known strategic problem in nascent markets, such as dominant design and product–market fit (thus, suggesting generalizability to other nascent markets); and (4) was undertaken by both firms. These innovations differed along relevant dimensions from prior innovation research, including complexity, ambiguity, and uncertainty. Following Davis et al. (2009), we define *complexity* as having many interrelated aspects or features, *ambiguity* as a lack of clarity or inability to perceive clearly, and *uncertainty* as a lack of predictability about what will happen (but not inability to perceive, such as where knowledge might be). This variation is a key strength of our study, enabling a more complete and generalizable theoretical framework.

The first innovation was the *quadrotor product architecture*. The architecture problem was ambiguous to find, but this simple innovation quickly became the dominant design and expanded the customer set to other hobbyists. The second was the *drone gimbal*, a groundbreaking stabilization innovation that enabled the "killer app" of video to take hold. Here, the video problem was uncertain to find and the gimbal was a moderately complex (i.e., not simple), novel (i.e., uncertain) innovation. It expanded the customer set to professional users and transformed the civilian drone from a weekend hobbyist toy into a "flying camera." The third innovation was the *"ready-to-fly" (RTF) drone*. The problem was obvious to find, but the RTF drone was a complex, novel innovation. It transformed the civilian drone from a DIY kit of hundreds of parts to a polished, mass-market product purchased at outlets such as Best Buy by commercial and consumer users (Table 3).

Cross-Case Analysis. As we compared across cases, we looked for themes and constructs as well as similarities and differences (see Navis and Glynn 2010, DiBenigno and Kellogg 2014, McDonald and Gao 2019 for paired case exemplars). In doing so, we looked for new constructs as well as likely ones (e.g., modular problem solving) (Eisenhardt 1989a). We used tables, charts, and other devices to enhance our analysis. In this creative process (Glaser and Strauss 1967, Eisenhardt 2021), we iterated among the six venture-innovation cases, such as by comparing within venture for different innovations and across ventures for the same innovation as well as random combinations. We used emerging patterns to form tentative constructs, relationships, and arguments grounded in theoretical logic and data and refined them via replication logic (Eisenhardt 1989a, Yin 2009). We brought in related literature to further ground the theoretical logic and iterated among constructs, theoretical relationships, and prior research until we reached a coherent theoretical framework.

Partway through this iterative analysis, we refined the performance measures to reflect how informants, including industry experts, assessed innovation performance. Specifically, we measured *innovation performance* by assessing the speed, quality, and outcomes of each innovation for each venture. Speed emerged as critical to performance, and this is consistent with prior work on venture performance in competitive nascent markets (Eisenhardt 1989b, Katila and Chen 2008). Specifically, we assessed a venture's *speed of finding* the problem associated with the focal innovation as the time from when individuals in the industry first identified the problem until venture executives identified the problem. We assessed *speed of solving* the problem as the time between the venture's finding the focal problem and launching its innovation as a product that solved that problem. To determine these dates, we triangulated informant accounts with archival materials (e.g., press releases, teaching cases) to provide more reliable estimates. To assess *innovation quality*, we collected data from multiple sources (e.g., users, industry experts, rivals) to assess the quality of the product associated with the focal innovation along dimensions used by these sources (e.g., reliability, ease of use, features). These assessments were highly convergent. Interestingly, faster innovation processes are associated with higher quality innovations, consistent with fit between organizing form and innovation characteristics.

We assessed the *outcomes* of the focal innovation for each venture: (1) quantitative measures for revenue, employees, and revenue growth in the year that the innovation was introduced (Figures 1, 2, and 3) and (2) qualitative assessments of the innovation and its tie to industry (and venture) growth per industry experts. These measures converge with each other and with the speed and quality assessments, yielding a robust view of a venture's performance vis-à-vis the focal innovation.

Despite beginning at the same time with similar resources and founders, a striking feature is the dramatic difference in innovation performance. Initially, COMM surpassed FIRM. Later, FIRM sped far ahead and COMM exited, providing a natural end point to our study. We turn now to how each addressed the three innovations that ground our theoretical framework and shaped the nascent civilian drone market.

Emergent Theoretical Framework

First Innovation (2007–2010): Quadrotor Product Architecture

The civilian drone industry emerged in about 2007. The initial product for both FIRM and COMM was a flight controller. They, however, used different product architectures: airplane (COMM) and helicopter (FIRM). These architectures had well-known trade-offs. Planes can fly for a long time and are safe but cannot carry a heavy load. Helicopters can carry more but have low range and are dangerous. Despite these trade-offs, neither entrepreneur saw the product architecture problem.

Figure 1. Revenue by Venture (as of Year End)

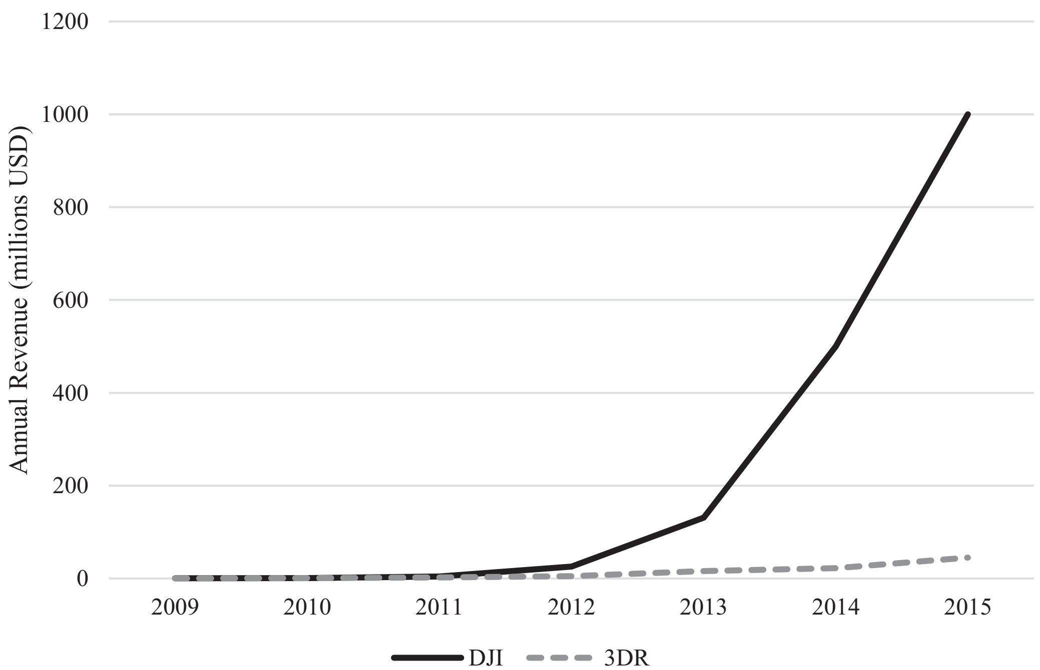
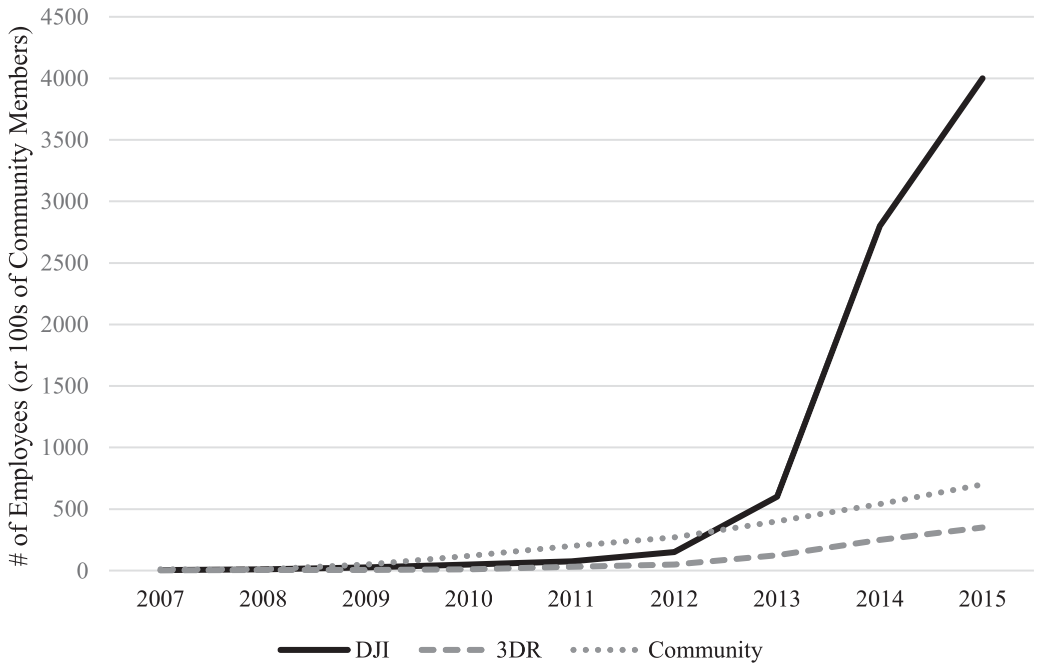
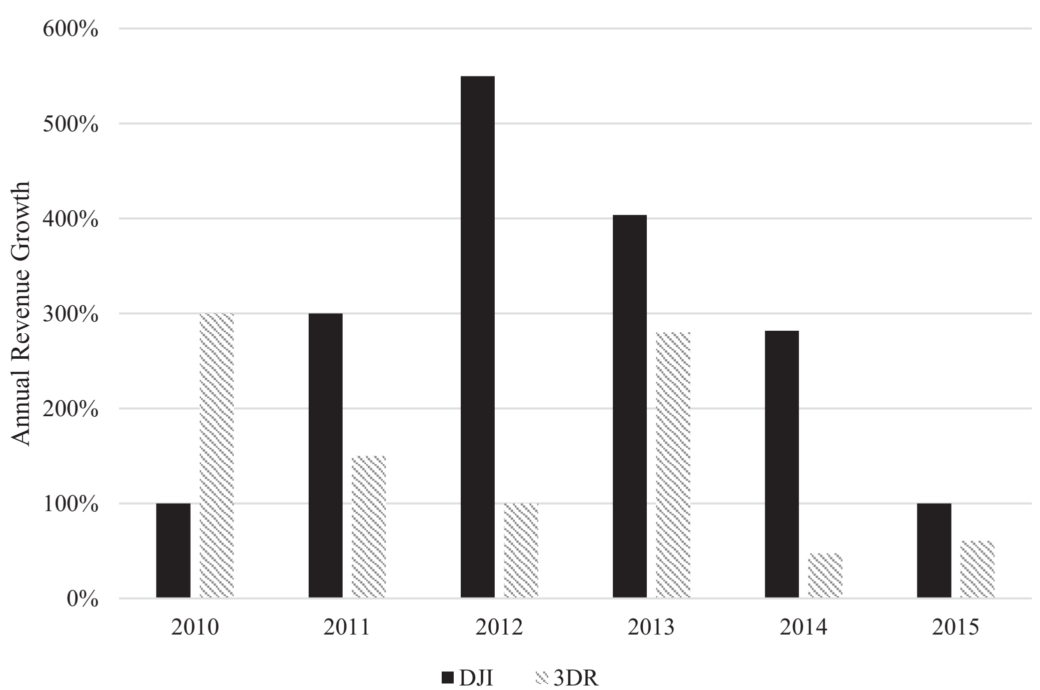


Figure 2. Employees by Venture and (Hundreds of) Community Members (as of Year End)



Finding the Product Architecture Problem (Dominant Design). Chris Anderson, primary founder of COMM, began the DIY Drones community for hobbyists in 2007. His aim was to learn about drones and explore communities with their "long tail of talent." He split his time as editor of *Wired*, flying drones, and building the community. Anderson promoted the community at conferences, maker fairs, and numerous speaking engagements. His efforts paid off. For example, DIY Drones rose to the top of Google search results. As a member described, "If you started Googling stuff on the web about drones and open source, you just

Figure 3. Annual Revenue Growth by Venture



couldn't get away from DIY Drones. It was sitting there at the top of the search results."

Consistent with being a community (Shah and Tripsas 2007, Lakhani 2016), people joined DIY Drones to exchange ideas about building and flying drones. As in many communities, these drone enthusiasts were largely amateur tinkerers. Participation was voluntary: anyone could join or leave. Members were unpaid and could self-select how they engaged with the community (Anderson 2012). DIY Drones initially attracted mostly people who wanted help with their hobby. As one member described his joining, "I was getting into RC, and I made a foamy RC aircraft. I wanted to turn it into an [first person view] flyer … There weren't very many resources for this, and DIY Drones happened to be a resource." Similarly, another member said, "I just got sucked right in immediately. I did my first post. Just being among all those people and exchanging information … Suddenly I was learning a lot more."

DIY Drones grew to more than 5,000 members in 2008 (per the DIY Drones online archive). In interviews with community members, we learned that most engaged by posting their experiences, asking questions, and individually experimenting, and a small number got involved in writing code and designing hardware. As in many communities (Shah 2006), the motives of these most engaged "core" contributors often evolved from seeking advice to creative work and personal enjoyment. For some, contributing to community projects was more creative than their day jobs. For others, it was fun. For example, one member was described as "an ex-Microsoft multi-gazillionaire. He's doing our UX, and he's doing it for fun. What else do you do when you retire from Microsoft?" We also learned that these contributors were often highly skilled, such as holding PhDs in fields such as electrical engineering. A member summarized, "It was people who were really amazed by what they could get this software and hardware to do at such a low cost."

In 2008, Anderson and a cofounder, Jordi Munoz, launched COMM as a for-profit venture to manufacture community-designed hardware and sell it mostly to the community. A member described it: "COMM was created by Jordi and Chris to basically sell the hardware that the open-source developer group [in DIY Drones] was creating." The cofounder expanded, "The initial model was there was a community, it created hardware and software, and then we [COMM] took the hardware element of it, and we produced it and sold it" Thus, COMM organized its innovation with a community-based form (i.e., a community chose and designed COMM's products). The rest of COMM was organized as a firm with Munoz leading a small manufacturing team of paid employees (per interviews). Anderson stated the modest goals: "Spread knowledge about drones and explore open source. The business side was all incidental."

By 2009, COMM was a growing hobbyist business. As a member observed, "COMM just started thriving." Describing the manufacturing function by which most employees worked, another member observed, "Jordi [Munoz] 'mom-and-popped' it basically from the ground up and to where it had dozens of employees." DIY Drones was also growing, surpassing 12,000 members (per the DIY Drones online archive). From interviews, blogs, and message boards, we learned that members often joined groups around interests such as racing and acrobatics. Anderson, who actively monitored the community, began noticing growing message board activity about the advantages of a new product architecture: quadrotor (per interviews, online article). As he noted, "The racing community found it [quadrotor], and people just started advocating around the community for its ease of use and safety." Although not interested in racing per se, he and a few core members immediately recognized the advantages of the quadrotor over the plane and helicopter architectures—for example, it was maneuverable and safe. In doing so, COMM found the ambiguous product architecture problem and its quadrotor solution.[5]

Meanwhile, FIRM took a different path. Frank Wang started FIRM with two HKUST engineering classmates in 2007 when they started working full time in a rundown warehouse. A cofounder described, "It was shabby with a short ceiling, a small open space about nine square meters … I didn't know such a small warehouse even existed." Initially, the team focused on designing its helicopter flight controller. As a cofounder said, "There were no sales, and so we didn't need to consider marketing. We mainly focused on solving technical problems."

As with COMM, FIRM's initial goals were modest. Wang noted, "I didn't know how big the market would be. I just wanted to make a product, feed 10 to 20 people, and have a team." FIRM organized its innovation (and the rest of FIRM) using the firm-based organizing form. Wang was the CEO and CTO. He led a small engineering team of paid employees, including his cofounders and later several engineers whom he hired on the internet. His engineers described Wang as a passionate perfectionist. One engineer said, "Frank called me often and suddenly to discuss ideas, regardless of the fact it was 3 a.m." Another engineer noted, "[Wang] would tell us, for each screw, how many fingers we should use."

Although FIRM was aware of the DIY Drones community, its engineers did not participate or actively monitor it. Believing that Wang was the ideal user, they did not see much benefit in the community. An engineer said, "Frank was the ideal customer in the early days." Wang explained, "If I like something, I don't care about why or others' opinions. I just want to realize it." Confident in their own ability, the FIRM team worked mostly alone using serial experimentation to improve components.

In 2008, FIRM (as did COMM) introduced its first product, a helicopter flight controller for hobbyists. As Wang said, "I just want to make an excellent product so that more people use it." Consistent with the firm form, FIRM also filed the first of many patents. FIRM's flight controllers sold in the Chinese hobbyist market and were higher priced and sold fewer units than COMM's. In 2009, a family friend invested and became VP of finance, and Wang's best friend from high school sold his apartment, invested, and became VP of marketing (per online article, interviews).

By 2010, COMM had switched to the quadrotor architecture. In contrast, FIRM stayed with the helicopter architecture and expanded to hobbyist distributors in a few countries. In 2011, Wang realized his mistake. As several informants told us, a New Zealand distributor surprised Wang with the simple fact that multirotors were outselling helicopters 20 to 1. Wang described his shift: "Initially, we didn't think much of multirotors … But when the dealer told us this information, we thought seriously about them." With this new information, another executive said, "The quadrotor was an easy and obvious decision."

Innovating the Quadrotor Product Architecture Solution. Consistent with the community form, DIY Drones members self-organized by breaking the problem into pieces (i.e., modular problem solving). Some adapted the community's flight controller software for quadrotors. As one member described, "So I put up my hand … There's a whole bunch of us. There's probably 30 people or so who jumped on that." Also consistent with the community form, a member noted, "Nobody was getting paid … We all had full-time jobs." One member (termed a "brilliant software engineer") took the lead. Another member described, "Over the space of a couple of weeks, [member] took the plane code and turned it into copter code." Others worked off his codebase, contributing bug fixes and feature improvements.

Another community member took the initiative on quadrotor hardware pieces. He sourced generic parts and designed a few components (e.g., frame and motor). He described his individual experimentation: "I experimented with the different materials to find which materials were strong enough, but as light as possible … Yeah, I went through probably something like 400 different motors … like 'let's change the magnet on this one, let's change the windings to be like this one,' and so on."

Consistent with the community form, COMM manufacturing employees worked with the community to improve the manufacturability of the community designs. As a member described, "We were sharing our design files and would give COMM feedback after looking over their designs. For example, 'You need to change this, change that.'" After three months and in 2010, COMM began manufacturing and selling DIY quadrotor kits. Anderson summed up the success, "That's what an open community can do!"

In contrast, FIRM switched to the quadrotor a year after COMM. Wang directed his engineers to repurpose their helicopter software. He explained, "Most of the stuff was the same." For hardware, the team heard about COMM's open-source designs and referenced them as a starting point. Another executive noted, "It was easy … We saw that somebody else had used the quadrotor design."[6] FIRM released its quadrotor flight controller in 2011 in about six months and its DIY kit of parts in early 2012.

Summary: First Innovation

The quadrotor product architecture was a major industry-wide innovation. It qualitatively transformed the product from a hodgepodge of aircraft architectures to the quadrotor as the dominant design. An industry expert noted, "Moving to the quadrotor was an unbelievably, extremely important decision." The market expanded to other hobbyists, such as robotics enthusiasts. Industry revenue increased about 10 times in 2010 (Figure A.2).

COMM's quadrotor components (especially its flight controller) were widely seen as the highest quality in the industry. Tying the quality of COMM's quadrotor innovation to its community organizing form, an expert praised, "It's hard not to be innovative when you have 100 scientists around the world whose passion is working on the flight code which is open source." Similarly, a member tied its low cost to community innovation, "Open source is the way to go. I don't know why more companies don't do it. It's much more efficient … and it's fun." COMM revenue grew about 300% in 2010 (Figure 3). A member noted, "Suddenly, COMM was making millions of dollars a year in revenue. Their stuff was so popular, they would always run out of product." FIRM grew, but less. Table 4 summarizes.

How did COMM find the product architecture problem a year earlier than FIRM and develop the quadrotor innovation in about half the time? First, COMM benefited from the task self-selection advantage of community-based organizing with individual experimentation (i.e., members' learning about their self-identified interests), leading to large-scale, diverse, and inexpensive exploration. This experimentation works well for finding ambiguous problems such as the product architecture problem. Although blurry and obscure for most members, this problem and its quadrotor solution became apparent to a community member with unique knowledge. This member was an aircraft enthusiast with deep knowledge of arcane architectures (per interviews, blogs). He described, "I've flown all sorts of things in my life." Given their size and diversity, communities often have at least some such members who "see" unexpected reframings (DeYoung et al. 2008, Weisberg 2015, Lifschitz-Assaf 2018). Recalling the obscure quadrotor architecture for full-sized aircraft from the 1960s, this member reframed his problem as product architecture (and its solution as the quadrotor). Given the free exchange of knowledge in communities, the quadrotor insight readily spread through DIY Drones and to COMM in 2010. In contrast, FIRM consisted of a small, homogeneous team (i.e., a few young engineers from HKUST) who were highly focused on FIRM's survival, making broad exploration and finding an ambiguous problem unlikely. FIRM found the problem a year after COMM.

Second, COMM also benefitted from the task self-selection advantage of community-based organizing with modular problem solving. Because members self-select their tasks and work independently, they choose pieces of a problem that they enjoy without much coordination (Baldwin and von Hippel 2011). Thus, modular problem solving fits well with *simple* (i.e., nearly decomposable) problems such as component parts for DIY quadrotor kits. Moreover, because members work for free and communities are often large relative to firms, modular problem solving by communities is especially cheap and fast—outcomes apparent in COMM's quadrotor innovation. Thus, COMM designed its high-quality yet low-cost quadrotor kits in about three months. In contrast, despite referencing the community's open-source designs as a starting point, FIRM's much smaller and less experienced engineering team took twice as long to design more expensive, sometimes lower quality parts.

A key point is whether well-known predictors of venture performance, such as founding team, goals, product meaning, and attention to rivals (e.g., Eesley et al. 2016a, McDonald and Eisenhardt 2020), are better explanations of innovation performance than organizing form. This seems unlikely. Per "Methods," both founding teams were unimpressive: small, without industry or entrepreneurial experience, and little functional diversity (Table 1). In contrast, high-performing teams are often large, multifunctional, and experienced (e.g., Eisenhardt and Schoonhoven 1990, Beckman 2006, Chatterji 2009). Both had similar modest initial goals, funding, customers, products, and product meaning. Neither was attentive to rivals. In other words, the two ventures were similar relative to well-known predictors of venture performance.

The more likely explanation is organizing form. COMM benefitted from the community's self-selection advantage with (1) individual experimentation for finding ambiguous problems and (2) modular problem solving for simple solutions. COMM inexpensively and broadly explored via the community and found the obscure product architecture problem. In contrast, FIRM had to pay its few engineers and focus their efforts in order to survive. Further, the community's large size (about 12,000 members) and diversity relative to tiny FIRM (less than 20 employees) amplified COMM's problem-finding and modular problem-solving advantages. Overall, our first insight is that the innovation processes of the community organizing form *fit* well with the (1) ambiguity of finding the product architecture problem and (2) low complexity of the quadrotor solution.

Second Innovation (2011–2014): Drone Gimbal

In 2011, COMM and FIRM (and others) began to recognize the possibility of a substantial civilian drone market. They started shifting from an initially modest goal to the ambitious goal of building a significant enterprise and began to seek VC investment. As a FIRM executive exclaimed, "It was super obvious that we were onto something hot." A COMM founder echoed, "We want to fill the skies with drones!" They (and others) saw similar uncertain possibilities around big data, photography, and vertical markets such as agriculture and construction. Yet it was apparent to both teams (and most observers) that the critical industry-wide bottleneck to growth was no killer app (i.e., product-market fit)—that is, a compelling product(s) for a significant group of buyers that would propel market growth beyond drone hobbyists. In a typical comment, an executive asked, "What is a drone good for?"

Finding the Low-Quality Video Problem (Product–Market Fit). We begin with FIRM. Like others, FIRM saw multiple yet uncertain possibilities for the killer app. A 2011 job posting explained, "FIRM is committed to the development of autonomous flying, vertical take-off drones for rescue, disaster investigation, air monitoring, transmission line inspection … a wide range of applications." The team considered waiting for a killer app to emerge. Instead, they decided to learn about multiple vertical markets using *parallel experimentation*—that is, coordinated learning to reduce targeted uncertainties about specific alternatives at once (Loch et al. 2001).

FIRM organized its parallel experimentation using a flexible "formula" of a few "simple rules" heuristics (Bingham and Eisenhardt 2011) (per interviews). The

Table 4. First Innovation: Quadrotor Product Architecture

	COMM		FIRM	
	Innovation process	Representative quotes	Innovation process	Representative quotes
Finding Problematic product architecture (Ambiguous problem)	**Individual experimentation:** Watched as community pursued own interests. Problem and quadrotor innovation solution brought together by insight of a community member racing drones.	"The initial model was there was a community, it created hardware and software, and then we [COMM] took the hardware element of it, and we produced it and sold it." (COMM cofounder) "What the community does best is remixing—exploring variation in what a product can be." (COMM CEO)	**Serial experimentation:** Small team of young engineers focused on iteratively improving helicopter drone DIY kits. **Chance:** Quadrotor as a solution came from a chance encounter with a NZ distributor.	"If I like something, I don't care about why or others' opinions. I just want to realize it. The flight control system enables me to control the helicopter easier. I believe other people will also like it." (FIRM CEO) "[CEO's] attention to detail is impressive … He would tell us, for each screw, how many fingers we should use and continue turning until we felt a certain type of feeling." (FIRM engineer)
Result	**Found:** 2010 **Speed:** one year	"The racing community found it [quadrotor], and people just started advocating around the community for its ease of use and safety." (COMM CEO)	**Found:** 2011 **Speed:** two years	"When the dealer told us multirotors were outselling helicopters 20 to 1, we thought seriously about multirotors." (FIRM CEO)
Solving Quadrotor product architecture (Simple, relatively certain solution)	**Modular problem solving:** Community members self-organized design of quadrotor components.	"Over the space of a couple of weeks [community member] took the plane code and turned it into copter code" (community member) "I experimented with the different materials to find which materials were strong enough, but as light as possible." (community member)	**Modular problem solving:** Team modified its helicopter software and developed hardware starting with community's designs.	"Most of the stuff was the same. We could use our software on multirotors … The hardware hardly needed any changes. So we made our first flight control for a multirotor in just a few months." (FIRM CEO) "It was easy … We saw that somebody else had used the quadrotor design." (FIRM executive)
Result	**Solved:** 2010 **Speed:** three months **Growth:** 300% (2010) Unlocked broad hobbyist market	"Suddenly, [COMM] was making millions of dollars a year in revenue." (community member) Turned hodgepodge of product architectures into quadrotor dominant design	**Solved:** 2011 **Speed:** six months **Growth:** 100% (2010)	"We continued spending money but barely made any." (FIRM cofounder)

first step was to pick tradeshows (especially in North America and Europe) in promising verticals—such as construction, real estate, and sports. Next, one or two executives would attend these tradeshows. For example, an executive described, "We went to a Chicago [entertainment] trade fair to come up with ideas. We also went to a toy trade show and an aerial photography show in Indianapolis." A third rule called for finding one or two tradeshow participants to be lead users. But finding lead users was not always easy because many dismissed FIRM as a "copycat" Chinese firm. The CEO described one incident, "The first time we went to an exhibition at Nuremberg, we were placed in the China section with one of those cheap and small booths, right next to stuffed animals." A final rule was working with these lead users to learn about drone applications (per interviews). One lead user was a German kayaker who helped FIRM learn about using drones for extreme sports. Another was a pilot who helped FIRM learn about using drones to fight California wildfires. One executive worked with Iowa farmers whom he met at a convention. He said, "We showed them how drones could show their whole field at once."

Parallel experimentation paid off within a few months when FIRM executives struck up a relationship at a tradeshow with the owner of an aerial photography business (per interviews, online article). This owner used helicopters (full-size ones) to do aerial photography in markets such as high-end real estate. He also knew about a lucrative application in Hollywood movies, for which aerial photographers charged thousands of dollars per day. As he told us, "If someone hired you for $10K to shoot for a day or two on a movie, and they weren't happy, there were 100 other movie companies that would hire you … People were willing to spend a lot of money." Yet, although aerial photography looked like a killer app, it also revealed a more accurate understanding of the underlying problem: low-quality video. An executive declared, "We gotta make something better than hobby garbage." Another executive expanded, "We learned that people in the movie industry were charging really high day rates for crappy [aerial] videos … So, if we could just make the footage really, really stable, we knew directors were gonna go crazy for it." They also realized that the critical innovation was a gimbal (i.e., a notoriously temperamental device that stabilizes movement). Thus, in early 2012, FIRM identified low-quality video as the problem blocking industry growth and its gimbal innovation solution.

Like FIRM, COMM also saw the uncertain killer app as the most pressing problem to find in 2011. In a typical comment, one executive asked, "We need to be the future, but the future of what?" Consistent with their community organizing form for innovation, COMM expected that a killer app would emerge from the community's individual experimentation as the quadrotor architecture had. They also saw no need to rush because they had a profitable hobbyist business. An executive explained, "We didn't have any particular urgency to find applications … We expected our users to find those." Another noted, "We're not really pressed because we were still doing really well on the hardware side." In fact, the team believed that they were uniquely situated to find the killer app because of their community-based organizing. Anderson explained, "There are like a zillion verticals out there; all of them are going to be transformed by drones. And we don't know anything about any of them, but we don't have to … because the community does."

During 2011–2012, COMM continued making and selling drone components and kits to hobbyists, and the community continued individual experimentation. As the CEO argued, "By making drones easy, cheap, and ubiquitous, we hope to put drones in the hands of regular people … maybe it will be windsurfers, maybe it will be agriculture, maybe it will be wildlife management." The COMM executive team (now with finance and marketing) discussed possible killer apps. One executive favored inspection of infrastructure such as bridges. Another saw the killer app as an empty space such as agriculture. The team, however, concluded that letting the killer app emerge from the community was the best way to find it. As before, COMM planned to adopt the community solution and scale up. An investor said, "You let loose hackers and the technology gets cheap; the hackers can go from the bottom … figure out all sorts of little applications for themselves … What happens after that is [those applications] give rise to commercially viable apps."

Consistent with the evolution of community–firm relationships (Shah and Nagle 2021), COMM became an active (and the only) sponsor of the community. COMM hired a community manager who gave out perks such as coffee mugs and hardware (per interviews, Anderson 2012). Yet the basic relationship remained the same. DIY Drones was still a community, and COMM still used community-based organizing for its innovation. Describing how COMM was both supportive and hands-off, a member noted, "COMM sponsored a lot of the product innovation. They actually built the boards that I designed … so COMM was very, very, very important to us in sponsorship. But they never really called the shots." The relationship was also advantageous to COMM. The community manager noted, "The beauty of community development was that we could put out a piece or a function for people to test, and we could get 10,000 hours of testing in a week because you get it out to so many people."

During 2011–2012, community-driven innovations proliferated. As the community manager told us, "There were lots of community-driven products, and

COMM was manufacturing those products." For example, members developed many small innovations such as one for fishing in hard-to-reach locations and a "follow me" feature so that the drone could follow its operator like a dog (per community interviews, blogs). Yet, unlike the quadrotor, the community did not converge on a killer app.

In late 2012, Anderson, who interacted with the community in online forums and at hobbyist events, noticed members adding a gimbal to stabilize video from strapped-on cameras such as GoPros (per interviews). A member had cobbled together a crude gimbal in mid-2012 (per community interviews, blogs). Others developed missing hardware and software pieces. COMM executives soon realized that around 60% of its drone kits were sold with a gimbal. Although temperamental and buggy, these gimbals improved video quality, and their popularity signaled video as the killer app.

Many members were satisfied with the video quality of the community-designed gimbal, calling it "just fine." But others told us it was "jittery." COMM concluded that this gimbal was too low quality for the significant market opportunity. As an executive said, "The community's gimbal is too jittery and buggy … not professional." Thus, in early 2013 (a year after FIRM), COMM found the low-quality video problem and its gimbal innovation solution.

Innovating the Drone Gimbal Solution. Drone gimbals are moderately complex. Although comprising only a few components, they require tightly integrated computer science, electrical engineering, and mechanical engineering. As one engineer emphasized, "A gimbal is a notoriously difficult thing to make work." Another said, "The challenge is that everything impacts everything. If you change something, you shift the balance." Further, a drone gimbal is also uncertain: unlike gimbals for other uses, it must be extremely small and light. It also had to be sufficiently high quality and inexpensive to supplant other aerial video solutions.

Consistent with the firm organizing form, FIRM selected an engineering team of existing employees and hired new engineers with missing skills. For example, a senior executive told us about hiring a valuable expert in mechatronics (i.e., rare combination of mechanical and electrical engineering). He said, "We hired a guy who knew how to integrate mechanical and electrical engineering. He'd done it before." Given the gimbal's moderate complexity (i.e., few components, many interactions), this engineering team organized learning with integrative problem solving—that is, working very closely together such that the entire team always had an evolving yet holistic understanding of the innovation (MacCormack et al. 2006).

Within its integrative problem solving, the gimbal team coordinated rapid *serial experimentation*—that is, a repeated learning process of trying a solution and updating it to incorporate feedback (Erat and Kavadias 2008). Specifically, they began with a prototype gimbal and then built, tested, and improved the gimbal design repeatedly. In fact, they sometimes repeated this learning cycle three to four times per day. As one executive explained, "We would make literally 20 prototypes on a weekly basis." Another described the process as "hardware iterations at extreme speed." A FIRM executive summarized this serial experimentation: "[FIRM] knows that their first prototypes are going to be terrible and the 15th prototype is going to be terrible, but by the 20th prototype, it's going to work pretty well. They never stop iterating."

FIRM launched its drone gimbal innovation in just under a year in late 2012. This high-quality innovation relieved the bottleneck to growth in the professional market for high-end aerial photography such as Hollywood movie-making. An executive noted, "The success of the product was all about the gimbal."

Meanwhile, COMM pursued another path. A community member developed a rough drone gimbal in mid-2012, but its video quality was too low for the large market opportunity. As the CEO explained, "It became clear that the barrier to improve designs was really high, and we needed professionals." The team debated how to organize this innovation: rely on qualified community members versus hire its own engineers. An executive noted the conflict, "The gimbal was a source of conflict. Some strongly believed that we needed to make our own gimbal. I was one of them."

Consistent with its community-based form for innovation, COMM finally chose the community. An executive noted, "There was this massive desire … to use the community to develop as much of the code as possible and even a lot of the mechanical design." Yet, now with the goal of becoming a significant enterprise, COMM also wanted to own the IP. As one executive said, "If you're making a product around users, you have to own the touchpoint." Also, the increasing popularity of drones had attracted cloners, making owning gimbal IP critical. These cloners were "ripping off" the community's open-source designs but not contributing. Anderson was torn: "In one sense, it's good for the world. Lower prices, more choice, more people working on it, and that's good. But ultimately … it's a race to the bottom." A member was blunter, "Open-source hardware doesn't work because of cloners. They're not contributing to the designs while we give away fully documented schematics and design files." A COMM executive lamented, "The open-source hardware business is cratering."

In addition, only a few community members had the technical skills to design a high-quality gimbal. A COMM engineer said, "You don't often get a ton of people in the community who can do this development … It's technically complex and obscure." Also, the few qualified members were dedicated to open source. A member described one of them, "He's legend! He's hardcore open source!" Thus, the relevant community members mostly rejected proprietary IP. As one described, "We're just struggling with their lawyers with the concept of open source." Another noted, "Our goals just diverged too much." A third elaborated, "[COMM] wanted to build a gimbal, and they came and asked us … So, I asked, 'Is this gonna be open source?' They just waffled back and forth. Couldn't even give the answer. And so we said, 'Okay, if we can't guarantee open source, we're not gonna do it.'"

In 2014 and with time passing, COMM desperately reached back to the community again. This time, as one community member explained, a few qualified members became "paid volunteers" and "bailed COMM out." Another member elaborated, "The community had to step in and finish the project … That was really tough." This gimbal was vastly better than the community's original design but well behind FIRM's high-quality gimbal that launched more than two years earlier. As a COMM executive summed up, "The gimbal was a bloody disaster."

Summary: Second Innovation

Like the quadrotor, the drone gimbal was a major industry-wide innovation. It qualitatively changed the product from a weekend hobbyist toy to a useful professional tool. By creating high-quality video, the gimbal relieved the bottleneck to growth in the lucrative high-end professional market for aerial photography. Industry revenue doubled in 2012 and again in 2013 as media and VC investment began to soar in 2013 (McDonald et al. 2019; Figure A.2). An expert tied this growth to video (and, thus, the gimbal), noting, "People aren't flying these drones just for the sake of flying them. They want to see perspectives. It's the key feature on any drone."

The gimbal was also a significant inflection point for FIRM. It was no longer seen as a cheap toy company. As the CEO said, "People in the industry began paying attention." A rival echoed, "FIRM was just not taken seriously until they did the gimbal." FIRM's growth soared —that is, \$4M in 2011 to \$131M in 2013 (Figures 1 and 3). FIRM changed the product meaning to a "flying camera" and began a new identity. An executive exclaimed, "We were flight control specialists; now we're flying camera makers!" An expert captured the gimbal's significance for FIRM and the industry: "While everybody has focused on FIRM being an innovative drone company, the gimbal is where we all need to focus and understand that's where the key innovation is." By comparison, COMM lagged. An executive lamented, "It was something that really only [FIRM] had—a gimbal that really worked." Table 5 summarizes.

How did FIRM find the low-quality video problem a year sooner than COMM and develop the gimbal innovation in about one third the time? One reason is that FIRM benefited from the coordination advantage of firm-based organizing with its parallel experimentation to find an uncertain problem. Parallel experimentation requires coordination in selecting where to learn (e.g., likely alternatives), what and how to learn, and how to share learning across alternatives. This process is fast and accurate when alternatives are independent and uncertain with the location of knowledge relatively well understood (Loch et al. 2001, Ozcan and Eisenhardt 2009). Because executives knew roughly where to look for the killer app, parallel experimentation fit well. That is, the missing knowledge was uncertain but not ambiguous. Indeed, framing the problem finding for the killer app in terms of uncertainty, an executive observed, "The two things that were not clear were which particular sector to target and when." In contrast, the community's individual experimentation was slow and inaccurate for finding the uncertain low-quality video problem. Although this learning process fit with finding the ambiguous product-architecture problem, it was less effective for finding an uncertain problem for which people knew roughly where to look for the missing knowledge.

Individual experimentation was also less helpful because DIY Drones members were no longer typical users given COMM's new goal of being a significant enterprise. Members were enthusiastic hobbyists who enjoyed "nerding out on weekends with their drones." They were tolerant of poor-quality video, calling it "just fine," although it was poor for other users. Moreover, although DIY Drones was geographically and technically diverse, it was also homogeneous—that is, mostly techy men. A member described the community as "middle-aged male engineers with prickly personalities." So the community was not suited to explore paths that interested other users. In contrast, although FIRM was also neither diverse nor general users, the firm-based form facilitated coordination of parallel experimentation that speeded accurate learning about users in likely vertical markets (e.g., farming, movie making).

Second, FIRM benefitted from its firm-based coordination advantage with integrative problem solving. That is, given firm-based organizing, FIRM could select an engineering team of relevant employees and new hires, attract them with high pay (described later), and direct their efforts as full-time members of a tightly focused team. Such integrative problem solving fits well with moderately complex and uncertain innovations such as the "notoriously temperamental" gimbal (MacCormack et al. 2006). By comparison, community-based innovation depends on having the right people show up—that is, self-selected members with the relevant skills. This probability is high when the community is large and for common skills such as general software. But it is less likely for rare and/or well-paid skills such as the gimbal required. In fact, few members were qualified. For software, a member explained, "There's a gillion people that can write basic gimbal software and have basic micro-controller talents … but only a few can do high quality." Another member echoed this rarity for hardware, "Anything with these high-speed signals is hard for the community to handle. Like nobody knows radio frequency engineering. You might find the ONE guy."

Also, although communities can engage in integrative problem solving, it can be difficult for geographically dispersed members to coordinate closely given time differences and episodic engagement (Faraj et al. 2015). An executive noted the coordination challenge for the community: "It was just trying to get a bunch of community members to come together and work in concert on a project that takes a very tight knot … You're developing a very complex, multifaceted product. Doing that with a dispersed team of open source, freelance guys who are just doing it because they love it—no matter how talented they are, that's just a really challenging thing to pull off."

Another COMM executive echoed, "It takes too many experts. To get that many people talking about the same things in the same room, those guys will be making a quarter of a million bucks at Google." A member summed up, "An OK gimbal is really easy to make. A great gimbal is really hard to make, and there is a huge jump between the two. The community never could make that jump."

Third, FIRM also exploited its coordination advantage with rapid serial experimentation. This learning process is effective for resolving uncertain problems with interdependence (i.e., complexity) because learning about one component provides information about others (e.g., Eisenhardt and Tabrizi 1995, Loch et al. 2001). Thus, serial experimentation is effective for products such as the gimbal. Yet, because this learning process is repetitive, serial experimentation requires focused attention that is not always interesting for community members or even possible given their "day jobs." Serial experimentation also requires coordination to transfer knowledge between trials (Erat and Kavadias 2008). Yet knowledge transfer can be spotty or slow in communities because participation is often episodic (Faraj et al. 2015).

A potential alternative explanation is that FIRM benefitted from the community. Although some employees may have engaged with DIY Drones, this explanation seems unlikely. With the gimbal and later the RTF drone, FIRM was technically well ahead of the community. As a COMM executive noted, "FIRM is about two years ahead in their technology." Further, the community's open-source licensing precluded proprietary use of its designs, making them profitable only for illegal cloners. Instead, FIRM pursued active patenting of its innovations beginning in 2008, used a top U.S. patent law firm (Wilson Sonsini), and filed hundreds of patents in the strong patenting regimes (United States, European Union) where it operated. A FIRM executive explained, "A drone is like an iPhone … It takes a lot of IP, which is sensible to patent." Finally, it was a point of pride at FIRM that they were *not* stereotypical Chinese copycats.

A more likely explanation is location—that is, perhaps FIRM's Shenzhen location determined the outcome. Yet this also seems unlikely. First, Shenzhen was not advantageous for finding the killer app. Rather, the killer app was found in Hollywood movie making—an hour flight from COMM. In fact, location arguably put FIRM at a disadvantage for learning about the non-Asian users that both ventures now targeted. For example, U.S. tradeshows were likely difficult for FIRM because of cultural and language differences. Nonetheless, FIRM identified the problem of low-quality video about one year earlier than U.S.-based COMM. Second, FIRM's location was not relevant for its firm-based advantages, such as hiring the right talent and coordinating parallel and serial experimentation. So, although FIRM's location near Shenzhen manufacturing likely accelerated the pace of serial experimentation, it seems unlikely to explain these firm-based advantages. Perhaps FIRM's success as a Shenzhen company seems obvious now. But, in 2012, as an industry expert told us, "Nobody believed that Silicon Valley's open source companies like Tesla and Apple iOS could be beaten."

The more likely explanation is that FIRM benefited from the firm-based coordination advantage with (1) parallel experimentation for finding uncertain problems and (2) integrative problem solving and serial experimentation for moderately complex, uncertain solutions. FIRM quickly and accurately found the uncertain poor-video problem by coordinating parallel experimentation in likely verticals. FIRM quickly and effectively designed a moderately novel (i.e., uncertain), complex gimbal by coordinating integrative problem solving and serial experimentation. Overall, our second insight is that the innovation processes of the firm-based organizing form *fit* with the (1) uncertainty of finding the low-quality video

Table 5. Second Innovation: Drone Gimbal

	COMM		FIRM	
	Innovation process	Representative quotes	Innovation process	Representative quotes
Finding No killer app Underlying low-quality video (Uncertain problem)	**Individual experimentation:** Watched and waited for community to find killer app.	"There are like a zillion verticals out there, all of them are going to be transformed by drones. And we don't know anything about any of them, but we don't have to…because we're the only open platform." (COMM CEO) "We didn't have any particular urgency to find applications… We expected our users to find those." (COMM CEO)	**Parallel experimentation:** Simultaneous learning about promising vertical markets. Simple rules "formula" guided (i.e., visit tradeshow, locate lead users, learn uses).	"We went to a Chicago [entertainment] trade fair to come up with ideas. We also went to a toy trade show and an aerial photography show in Indianapolis." (FIRM executive) "We worked with farmers… We showed them how drones could show their whole fields at once… That was really important." (FIRM executive)
Result	**Found:** 2013 **Speed:** two years Saw 60% of COMM drones sold with gimbals. Then learned low-quality video was underlying problem	"All of the sudden, this gimbal kind of popped up out of nowhere." (COMM executive)	**Found:** 2012 **Speed:** one year Learned low-quality video was underlying problem.	"If we could just make the footage really stable, we knew movie directors were gonna go crazy for it." (FIRM executive)
Solving Drone gimbal (Moderately complex, uncertain solution)	**Integrative problem solving:** After realizing community designs lacked sufficient quality, team of "paid volunteer" members worked together.	"In the beginning, we would take [community] designs and improve them a little bit and manufacture them. But, over time, it became clear that the barrier to improving designs was really high, and we needed professionals." (COMM CEO) "The community bailed COMM out [on the gimbal]." (community member)	**Integrative problem solving:** Team of employees and new hires w/essential skills worked closely together. **Serial experimentation:** Rapid iterations of product designs	"We hired a guy who knew how to integrate mechanical and electrical engineering. He'd done it before." (FIRM executive) We kept pumping out hardware iterations at extreme speed." (FIRM executive)
Result	**Resolved:** 2015 **Speed:** more than two years **Growth:** 100% (2012)	"The gimbal was a bloody disaster." (COMM executive) "The inability to get the gimbal to work on time was devastation to COMM." (industry expert)	**Resolved:** 2012 **Speed:** nine months **Growth** 550% (2012) Unlocked professional market, especially high-end aerial photography	"FIRM was not taken seriously until they had the gimbal." (Rival executive) "The real innovation was the gimbal." (Industry expert) Turned weekend toy into a flying camera (i.e., useful professional tool)

problem and (2) moderate complexity and uncertainty of the drone-gimbal solution.

Third Innovation (2012–2015): Ready-to-Fly Drone

In 2012, the civilian drone industry comprised hobbyists and some professionals buying components and DIY kits. COMM and FIRM were now pursuing the goal of becoming a significant enterprise. Both had raised VC funds including in Silicon Valley (COMM $5M, FIRM $1M). Yet an industry-wide bottleneck limited growth. The problem was obvious: most commercial and consumer users were not interested in assembling hundreds of parts and installing software (i.e., product–market fit). A FIRM executive noted, "Probably 80% of our leads would drop off … trying to learn how to put this thing together." A COMM executive echoed, "The marketplace has spoken clearly on this—not everyone wants to use a soldering iron or load code." The innovation to solve this problem was also obvious: an RTF drone—i.e., a fully integrated product right "out of the box."

Innovating an RTF Drone. Although finding the assembly problem was certain (i.e., obvious), the RTF innovation solution was not. Rather, an RTF drone is complex (i.e., many components and interrelationships) and uncertain. It combines multiple disciplines: computer science; telecommunications; and electrical, aeronautical, and mechanical engineering. It has many more components than a gimbal—some of which are themselves complex, such as the camera. These components have many interrelationships, complicated by size and weight constraints. Magnetic interference, for example, can degrade flight controller performance. As one observer noted, "[RTF drones] are so hard to build. You think you have it figured out, but there are so many moving parts and software pieces and components." Another echoed, "Designing a drone is hard!"

We begin with FIRM. FIRM began the RTF drone innovation in 2012 by using *hybrid problem-solving*—that is, a problem-solving approach that transcends modular and integrative problem solving (Baumann and Siggelkow 2013, Ott and Eisenhardt 2020).[7] That is, engineers initially built a rough working drone with off-the-shelf components held together with zip ties and duct tape (per interviews). They then organized learning to redesign each component one by one, deliberately focusing successively on what they saw as the most critical remaining component. Although experimenting to improve the design of each focal component, the engineers also organized repeated tests of the entire product (i.e., system) to ensure the drone could always fly. They repeated this process with successive components until the entire solution was complete about 18 months later (per interviews). A FIRM executive explained, "We start with off-the-shelf parts and prototype the whole design. Then, gradually, we replace key modules one by one and design and make them ourselves." Another colorfully noted, "We duct tape and zip tie the thing together to show it kind of works and then just make literally 20 prototypes on a weekly basis, constantly building a new prototype, constantly replacing the zip ties with better parts, replacing some crappy brace with a better brace, and so on."

Within its hybrid problem solving, FIRM used parallel experimentation with competing teams (per interviews, online article) to design specific component solutions. An engineer described, "Pitting teams against each other and having one win is how product development works inside of FIRM." This required coordination, such as organizing employees into teams and creating simple rules (i.e., heuristics) that provided a flexible yet efficient formula for the competitions (Bingham and Eisenhardt 2011). One rule called for using competing teams for critical (not all) components. An engineering manager elaborated, "We use competitions between product design teams in-house. We especially do this with critical components. The teams compete, and then we see who wins … We don't do that all of the time, but we do for the most important component." Other rules called for using two teams, keeping teams small (three to eight), and breaking up the losing team. Another manager described, "There would be a team anywhere from three to eight engineers working on a given subsystem [e.g., camera, airframe] … Two different teams of engineers working in silos to create the mainboard or whatever. And then, by the time they got to prototype number two or three, it was decision time about which team had a better working model … And that team got to stay together."

Finally, FIRM often used serial experimentation, much as with for the gimbal. FIRM launched two early RTF drones and then the industry's first complete RTF drone, including a camera and gimbal in late 2013.

Meanwhile, COMM took a different path. After briefly working with the community, COMM decided that a purely community-designed drone would have insufficient quality for a mass-market product. An executive described, "Community designs have wires hanging out … they're just too raw, not consumer." So they set out to design their own by combining community- and firm-based organizing.[8] That is, they used elements of the community form: members self-selected tasks and shared IP. With VC funding, COMM also used elements of the firm form: hired experienced engineers and paid specific community members with critical expertise to dedicate more time. Yet, this blurred the line between organizing as a community versus firm. A manager mused, "Are they

COMM people, or are they community people? It's kind of a gray area."

COMM relied on modular problem solving. This works well when components are independent (e.g., Lakhani et al. 2013). Modular problem solving (which optimizes individual components) also fit with COMM's plan to base its RTF drone on components from its DIY kits. An engineer observed, "We had gotten really good at building autopilots and GPS and the various ancillary bits that you need to put into a drone." Yet, unlike FIRM's hybrid problem solving, modular problem solving misses learning about component interrelationships (e.g., magnetic interference, heat buildup)—problematic for a complex product such as an RTF drone. Further, because RTF drones are novel (i.e., uncertain), it was almost impossible to plan ahead for these interrelationships. Thus, community members and COMM engineers organized their learning to design components that worked in DIY kits but often failed together in an RTF drone. An expert noted, "They're approaching building autonomous vehicles like they're creating software." An executive summed up, "COMM never solved the integration stuff."

Like FIRM, COMM valued rapid serial experimentation. Indeed, they had a tight link between engineering and manufacturing. A community member described, "That's the one thing that COMM has: good prototyping capability. You could run a small batch of boards readily." He went on, "The manufacturing side of things and the design side of things and the software development side of things—it is all very tightly coupled." Yet, relative to FIRM, the pace was slow. Instead of prototyping designs several times per week, the CEO explained that COMM would "wait for the community designs to come in" and prototype about once a week.

COMM also tried parallel experimentation, but task self-selection by community members impeded coordination, making the process more like individual experimentation. A new engineer employee noted, "All COMM did was experiments. But it wasn't like team-oriented engineering. It was just people doing little experiments here and there—one guy working on open source, one guy working on a mapping thing." Keeping community members coordinated was also difficult. A COMM employee engineer noted, "The community doesn't know the product goals, and they don't know what we're trying to do." Another described that physical products, such as drones, are hard to design with the remote part-timers: "It [part-time] just doesn't work … You need to be closer to manufacturing."

In addition, many community members preferred to work on community projects. An engineering leader complained, "It took 'missionary work' to find community members to work on the drone." The community and COMM also had conflicting values. A lead COMM engineer described, "So, basically, the engineering leadership and the community battled constantly. The community was like, 'You guys should be making hobbyist stuff. You can get the parts and glue it together with bolts exposed and whatnot.' And we're like, 'We wanna be able to sell this thing at Best Buy.'"

COMM introduced an incomplete RTF drone in early 2014, more than a year after finding the assembly problem. However, it was rough. For example, it still required some assembly. It also lacked major features, such as an integrated camera. An executive noted, "COMM as a kind of DIY-maker company was getting left behind … We needed to get our act together." Another echoed, "We needed to level up and create a polished consumer product."

This underperformance prompted COMM to switch fully to firm-based organizing. With $30M in new VC funding, they acquired a team of experienced engineers to redesign the RTF drone almost from scratch. The CEO noted, "The less we were using any open innovation, the more we were just being a traditional company." With the new engineering team, COMM launched its RTF drone in 2015. Many observers believed the drone was excellent. The press celebrated the product as "the smartest drone ever" (Newton 2015). Finally, after three years and well behind FIRM, COMM had its RTF drone.

Summary: Third Innovation

The RTF drone was a major industry-wide innovation. It qualitatively changed the product from a DIY kit of hundreds of parts for hobbyists and a few professionals to a polished mass-market product for commercial and consumer users. An industry expert observed, "FIRM had a great system—camera, safety, transfer to your phone." Industry revenue exploded—doubling in 2013 and quadrupling in 2014 (Figure A.2). A prominent analyst tied this growth to FIRM's RTF innovation, "FIRM reinvented the industry. The Phantom [FIRM's first RTF drone] really bridged the gap between a toy and tool. They became the 800-pound gorilla." Indeed, FIRM grew to $130M in 2013, and reached $1B in revenue and more than 80% market share in 2015 (Figures 1 and A.2). Behind, COMM soon exited. Table 6 summarizes.

How did FIRM develop the RTF drone innovation sooner (two years) and faster (in about one third the time) than COMM? First, FIRM benefitted from the coordination advantage of firm-based organizing by using superior experimentation to learn quickly and accurately about many specific uncertainties. Parallel experimentation to design components with competing teams required coordination: assemble teams, assign them to a component, choose the better design, and repeat. Serial experimentation also required coordination, such as learning between iterations (see gimbal). In contrast, COMM's parallel experimentation was poorly coordinated—that is, often based on self-selection of tasks consistent with its community form. Its serial experimentation was slowed, in part, by part-time contributors.

Second, FIRM also benefitted from its coordination advantage with hybrid problem solving. This requires coordination to organize learning to focus sequentially on the most critical components one at a time while maintaining a holistic yet evolving understanding of the entire design. Hybrid problem solving works well for uncertain, complex innovations such as the RTF drone (Baumann and Siggelkow 2013, Ott and Eisenhardt 2020). In contrast, COMM's organizing form that mixed community and employee engineers was difficult to coordinate. Its modular problem solving misfit with the many uncertain interactions among RTF drone components—that is, COMM innovated the drone as if it were modular like software when it is a highly integrated product like an iPhone.

More subtly, FIRM benefited from the incentives of the firm-based form (e.g., team competitions, bonuses for winners, high salaries) to align employees (Wu and Lee 2013). In contrast, community-based organizing relies primarily on incentives, such as common good and personal learning. Initially, this was not problematic. In fact, the engineers in the COMM community were widely regarded as better than those at FIRM. Yet, over time, FIRM built a large, skilled engineering group that likely matched and probably exceeded the community. A COMM executive described the new situation, "FIRM had the upper hand with a whole bunch of engineers that are really good engineers and they know about drones and they work 70 hours a week—only for one company. There is no other company like that."

In contrast, the community and COMM became increasingly misaligned. A COMM manager noted, "Their value structure became completely noncompatible." An engineer employee asked, "Is open source a religion?" Community members blamed COMM, and COMM did the reverse. An executive complained, "It was just people who thought it was cool to make drones do autonomous behavior for cheap." An engineering leader summed up COMM's frustration, "All you need to do is make a product that enough people love. That is just not language the open source guys understand."

Overall, FIRM benefited from the coordination advantage of firm-based organizing for (1) parallel and serial experimentation and (2) hybrid problem solving for complex, uncertain solutions. Thus, our third insight is that the innovation processes of the firm-based organizing form fit well with the complexity and uncertainty of the RTF drone solution. Perhaps if COMM had stayed with its original business or adopted firm-based organizing sooner, it might have succeeded. Alternatively, COMM might have learned to work with the community by negotiating a mutually acceptable boundary given more time (O'Mahony and Bechky 2008).[9] COMM, however, did not have more time in a high-velocity nascent market with a surprisingly skilled rival. As an executive ruefully noted, "We thought we were competing against a traditional 20th-century Chinese company, but instead we encountered a true 21st-century Chinese thoroughbred."

Discussion

Our primary theoretical insight is that the firm organizing form for innovation performs best relative to the community form for firms in nascent markets—that is, uncertain, often high-velocity settings with novel, frequently complex problems. Specifically, the firm organizing form has a coordination advantage that enables quickly and accurately targeting innovation processes to reduce the many specific uncertainties that characterize these markets. In contrast, although communities can be helpful in nascent markets, the task self-selection advantage of communities works best in stable settings such as established markets with simple (i.e., nearly decomposable) products and in ambiguous settings in which low-cost randomness pays off. Broadly, we also contribute a theoretical framework for how organizing form and problem type jointly shape innovation performance. By focusing on nascent markets, we add problem finding and expand the repertoire of innovation processes that address uncertainty well. Most importantly, we crystallize that uncertainty forms the boundary condition for when firms should rely on firm-based (versus community-based) organizing for their innovation.

Organizing Innovation in Nascent Markets: Community or Firm

We contribute a theoretical framework to the literature on innovation in nascent markets (e.g., Furr 2019, Davis and Eisenhardt 2011, Zuzul and Tripsas 2020) and comparative organizing form (e.g., Baldwin and von Hippel 2011, Puranam et al. 2014). Prior theory argues that the community organizing form may be more effective than the firm one for several reasons: lower cost (Baldwin and von Hippel 2011, Alexy et al. 2017), greater flexibility (Fjeldstad et al. 2012, Felin and Powell 2016), individual experimentation enabling broad exploration (Felin and Zenger 2014), and modular problem solving (Baldwin and von Hippel

Table 6. Third Innovation: RTF Drone

	COMM		FIRM	
	Innovation process	Representative quotes	Innovation process	Representative quotes
Problem Finding Assembly hassle (Certain problem)	**Obvious:** Significant lost sales and customer complaints	"The marketplace has spoken clearly on this—not everyone wants to use a soldering iron or load code." (COMM CEO)	**Obvious:** Significant lost sales and customer complaints	"Probably 80% of our leads would drop off … trying to learn how to put this thing together, and potentially having it not work out." (FIRM executive)
Result	**Found:** 2012 **Speed:** less than three months		**Found:** 2012 **Speed:** less than three months	
Problem Solving RTF drone (Complex, uncertain solution)	**Modular problem solving:** Select community members and COMM engineers design specific components to be combined into RTF drone. **Serial experimentation:** Prototype about once per week to iteratively improve designs. Slow pace. **Individual/parallel experimentation:** Mostly uncoordinated multiple explorations to improve drone components.	"We had gotten really good at building autopilots and GPSs and the various ancillary bits that you need to put into a drone." (COMM executive) "We didn't really have a lot of vehicle [system] development experience." (COMM executive) "COMM never solved the integration stuff. Why? They weren't product people." (COMM engineer) "All they did was experiments. But it wasn't like a team-oriented engineering team. It was just people doing little experiments here and there." (COMM engineer)	**Hybrid problem solving:** Sequential focus on remaining most critical component while always having a working drone. **Serial experimentation:** Several prototypes per week to iteratively improve designs. Fast pace. **Parallel experimentation:** Simultaneous exploration by competing teams for focal critical components Simple rules formula (e.g., two teams, three to eight members).	*"We start with off the shelf parts and prototype the whole design. Then gradually we replace key modules one by one, and design and make them ourselves."* (FIRM executive) *"We duct tape and zip tie the thing together to show it kind of works, and then just make literally 20 prototypes on a weekly basis."* (FIRM executive) *"We use competitions between product design teams in-house. We especially do this with critical components. The teams compete, and then we see who wins."* (FIRM engineer
Result	**Solved:** 2015 **Speed:** three years **Growth:** 250% (2013)	"We eventually launched [RTF drone]. It did OK … But it was too late." (COMM executive)	***Solved:*** 2013 ***Speed:*** 1 year ***Growth:*** 400% (2013) Unlocked commercial and consumer markets	*"FIRM re-invented the industry … They became the 800-pound gorilla."* (Industry analyst) Turned a DIY kit into a mass market product sold at Best Buy

2011). In contrast, our framework indicates that the firm organizing form often performs better relative to the community in nascent markets (Table 7). There are several reasons.

First, firms have a coordination advantage in using rapid serial and parallel experimentation—that is, learning processes that are particularly useful for addressing uncertainty. These experimentation processes can be effectively coordinated by formal authority. When this occurs, these processes quickly and accurately target effort on reducing the many specific uncertainties that characterize nascent markets. In contrast, communities are built around the advantages of individual experimentation that derive from task self-selection (e.g., Felin and Zenger 2014). Although communities can engage in serial and parallel experimentation, they are often hampered by the episodic engagement of part-time members and their idiosyncratic preferences for particular self-selected tasks.

Second, firms also have a coordination advantage in using rapid integrative and hybrid problem solving—that is, problem solving approaches that are useful for the novel (i.e., uncertain), complex (i.e., many and many interrelated components) problems that often occur in nascent markets. Integrative and hybrid problem-solving approaches can be usefully coordinated by formal authority. When this occurs, these approaches can quickly and accurately organize learning—that is, prioritize what, how, and when to learn while maintaining an evolving understanding of the entire solution. In contrast, communities are built around the advantages of modular problem solving by many independent members that flow from task self-selection (e.g., Baldwin and von Hippel 2011). So, although communities can engage in integrative and hybrid problem solving, they are often hampered by the episodic engagement of part-time, dispersed members. This engagement makes both an evolving, collective understanding of the entire solution and effective organization of learning difficult to achieve.

Finally, firms have a coordination advantage for organizing rapid innovation that is useful in nascent markets. Here, because industry structure, rivalry, product definition, and product–market fit are often quickly changing, speed matters (Eisenhardt 1989b, Hannah and Eisenhardt 2018). Firms can often hire the right top talent full time, offer motivating financial incentives, and avoid time-consuming negotiation of IP ownership—all useful for speeding innovations. Of course, some innovations do fit well with the community form. As with COMM's quadrotor, communities can act rapidly when the problem is ambiguous such that the low-cost randomness of individual experimentation pays off and when the solution is simple such that many members can work simultaneously on self-selected tasks. Yet, as with DIY Drones and COMM, an effective community–firm relationship requires a clear separation such that it is unmistakable who is a community member, their tasks, and IP rights—clarity that is difficult to negotiate and maintain in nascent markets as COMM discovered.

Overall, the firm's coordination advantage is broadly useful for organizing the innovation processes that rapidly and accurately reduce the many specific uncertainties that characterize nascent markets. In contrast, although community-based organizing can use individual experimentation for broad exploration and inexpensive modular problem solving (Fjeldstad et al. 2012, Felin and Powell 2016), these processes are often narrowly useful in nascent markets. In sum, we (1) provide a process view of innovation in nascent markets, (2) expand the repertoire of relevant innovation processes, and (3) highlight the key distinguishing mechanisms of organizing form—that is, coordination versus task self-selection.

Toward an Expanded Theory of Comparative Organizing Form

More broadly, we contribute to the theoretical understanding of how organizing form and innovation type jointly shape innovation performance. That is, by focusing on nascent markets, we expand the comparative theoretical literature in several ways (e.g., Baldwin and von Hippel 2011, Afuah and Tucci 2012, Puranam et al. 2014). First, we contribute problem finding. Prior comparative work focuses on problem solving (e.g., Baldwin and von Hippel 2011, Felin and Zenger 2014). Yet we observe that problem finding is also critical—that is, problem finding affects the timing and accuracy of the starting point for problem solving. A head start can be advantageous in nascent markets where speed is often consequential. For example, fast, accurate problem finding gave the earlier venture (e.g., COMM product architecture, FIRM low-quality video) a head start. A head start, in turn, makes earlier products and revenue more likely. A head start can also create competitive advantage when imitation barriers emerge, such as declining manufacturing costs, favorable brand, and IP such as FIRM enjoyed with its RTF drone innovation.

Second, we contribute a more complete view of innovation processes to the comparative theoretical literature. Prior work highlights individual experimentation for broad exploration and modular problem solving for simple problems (e.g., Baldwin and von Hippel 2011, Felin and Zenger 2014). By focusing on nascent markets, we contribute a more complete repertoire—that is, parallel and serial experimentation for resolving specific uncertainties and integrative and hybrid problem solving for organizing learning to

Table 7. Theoretical Framework: Fit of Organizing Form and Problem Type

Organizing form	Firm	Community
Problem finding	Uncertain	Ambiguous
Problem solving	Uncertain Complex	Certain Simple Ambiguous
Source of advantage	Coordination	Self-selection
Problem solving processes	Integrative or hybrid	Modular
Experimentation processes	Serial and/or parallel	Individual
Settings	Nascent markets Uncertain and/or complex problems	Established markets Ambiguous, certain and/or simple problems
Exemplar	Drone gimbal RTF drone	Quadrotor product architecture

Note. When problem is obvious (i.e., certain), both organizing forms are effective for problem finding (e.g., RTF drone).

solve novel, complex problems well. Third and most important, we contribute an emphasis on uncertainty, including disentangling it from ambiguity when characterizing types of problems and, thus, their relevant innovation processes. Indeed, uncertainty forms the boundary condition for when the firm organizing form is preferred.

Innovation, Bottlenecks, and Growth in Nascent Markets: Portrait of an Exceptional Firm

We also contribute to the emerging literature on how firms grow in nascent markets, including the transition from venture to adolescent firm (e.g., McDonald and Eisenhardt 2020, Tidhar et al. 2021). We provide a portrait of an exceptional firm—one that went from three young engineers in a rundown warehouse to a $1B global market leader in under a decade. A key point is that by (1) finding major industry-wide problems that were the critical bottlenecks to growth (i.e., dominant design and successively better product–market fits), and (2) solving them with significant innovations that erected barriers to imitation for others, FIRM grew the market and itself. Thus, innovation processes applied to successive bottlenecks helped to drive both FIRM's growth and the growth of the civilian drone industry. As an expert noted, "FIRM reinvented the industry … They became the '800 pound gorilla.'"

Potential Alternative Explanations

As in all research, it is essential to address potential alternative explanations. As noted earlier, similarities such as founding team, product meaning, funding, and goals are unlikely alternative explanations. A more plausible one is that FIRM's Chinese location conferred advantages beyond speed because of proximity to Shenzhen manufacturing (discussed earlier). Possibly, for example, FIRM benefited from loose Chinese regulation. Yet, in our interviews, both COMM and FIRM executives dismissed a regulatory advantage. As a COMM executive explained, "The playing field earlier on, in 2012 and 2013, was even. It wasn't like any place had regulations built up. Nobody knew anything. Most countries had nothing." In comparing COMM and FIRM, a high-profile industry expert echoed, "Regulation was not a first-order driver of the heterogeneous performance." Thus, our study plays out before regulation is even possibly relevant. Finally, as they grew, both targeted customers in the same North American and EU regulatory regimes.

Perhaps FIRM benefited from Chinese government funding or other assistance. Yet this also seems unlikely. During our study, FIRM was one of many small Chinese drone ventures. As one Chinese VC told us, "There were hundreds of drone start-ups in China. There was nothing special about FIRM." Further, there is no evidence that FIRM received government help during our study (this may have changed post-study with FIRM's success). As a well-placed Chinese informant told us, "Government funding was very unlikely." In fact, FIRM (as did COMM) gained most of its funds from North American VCs.

Finally, perhaps FIRM benefited from the Chinese culture. For example, high *cultural tightness* in China—that is, strong social norms and low tolerance for deviant behavior (e.g., Gelfand et al. 2006, Chua et al. 2015)—may have improved FIRM's outcomes. Yet the cultural explanation is also unlikely to be material. For example, FIRM's excellent innovation processes, such as parallel experimentation and hybrid problem solving, are not particularly Chinese. Instead, they are cutting-edge practice in the United States and other countries (e.g., Thomke 2003, Murray and Tripsas 2004, Ott and Eisenhardt 2020). Although Wang (similarly to many Chinese executives) is a strong figure, so too are U.S. executives such as Jeff Bezos, Elon Musk, and Steve Jobs. Indeed, Wang sought to emulate Jobs and Apple. As a close observer noted, "Frank was obsessed with being Apple." FIRM was also global with strong ties to top U.S. VCs (Sequoia) and patent attorneys (Wilson Sonsini). In fact, a rival described FIRM as "more like a Silicon Valley start-up than a historical

Chinese company." Finally, if culture did play a significant role, we would expect FIRM to be *less* innovative than COMM and other non-Chinese rivals. In fact, the cultural and institutional factors in China are widely recognized as *inhibitors* of innovation (Yang et al. 2013, Abrami et al. 2014, Eesley et al. 2016b).[10] Instead, FIRM defied the stereotype of Chinese copycat and became the global leader.

Boundary Conditions

It is also important to consider boundary conditions. A key one is whether our theoretical framework generalizes to *established firms* in nascent markets. Our insights assume that the firm form has a coordination advantage that enables rapid, targeted use of innovation processes such as parallel and serial experimentation. Is this assumption valid for established firms? On the one hand, established (i.e., larger and older) firms are likely to be less flexible than ventures such as those we study. For example, they may face rigidities arising from internal politics (e.g., Kaplan 2008, DeSantola and Gulati 2017), cognitive inertia (e.g., Tripsas 1997, Ott et al. 2017), and excessive structure (e.g., Gilbert 2005, Davis et al. 2009). On the other hand, many established firms are participating in an innovation renaissance using fast, flexible approaches, such as agile and lean start-up. Traditional established firms such as Microsoft, Ford, and Walmart are joining newly large firms such as Airbnb and Spotify in actively using innovation processes such as parallel and serial experimentation (Kohavi and Thomke 2017). Thus, we think that our framework probably generalizes to established firms in nascent markets. That said, simply being a firm or using firm-based organizing for innovation does not guarantee success, especially given the tendency toward rigidity among some established firms. This is an ideal avenue for future research.

A second boundary condition is whether our theoretical framework generalizes to *established communities* in nascent markets. On the one hand, established communities often coordinate better than new communities such as DIY Drones (O'Mahony and Bechky 2008). So, perhaps COMM would have fared better with an established community such as Linux or OpenIDEO. Some established communities also add firm organizing elements such as financial incentives and targeted hires to improve (Lakhani at al. 2020). On the other hand, established communities often rely on task self-selection by part-time members, may have talent gaps for rare or highly paid skills, and favor open-source IP. Further, established communities may engage many members only briefly (Piezunka and Dahlander 2019) or be unable to maintain the requisite clear separation with the firm in a nascent market (discussed earlier). Finally, as with firms, communities may ossify (Halfaker et al. 2013). Thus, our framework probably generalizes to established communities in nascent markets. That said, firms that rely on established communities will likely innovate better than with new ones although simply working with an established community is unlikely to overcome the other disadvantages of the community form in nascent markets. This is another avenue for future research.

Conclusion

Our aim is to shed light on how organizing form influences the innovation performance of firms in nascent markets. Based on a rare empirical comparison of community- versus firm-based innovation by two ventures in the nascent civilian drone industry, we contribute a theoretical framework that offers fresh insights for the literature on comparative organizing form and innovation in nascent markets. Organizing innovation with a community often works well in stable settings such as established markets with simple (i.e., decomposable) products, such as snowboards, Wikipedia, and modular software, and in ambiguous settings in which low-cost randomness pays off. The firm-based form can also work in these settings but performs best relative to the community form in nascent markets—that is, uncertain, often high-velocity settings with novel, frequently complex products.

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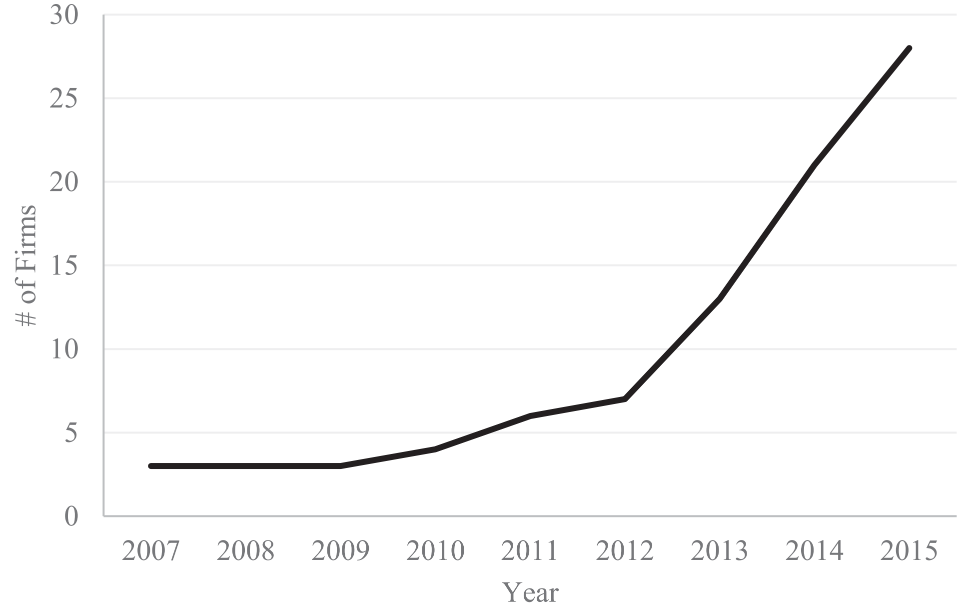
Appendix

Table A.1. Civilian Drone Industry Timeline: COMM and FIRM

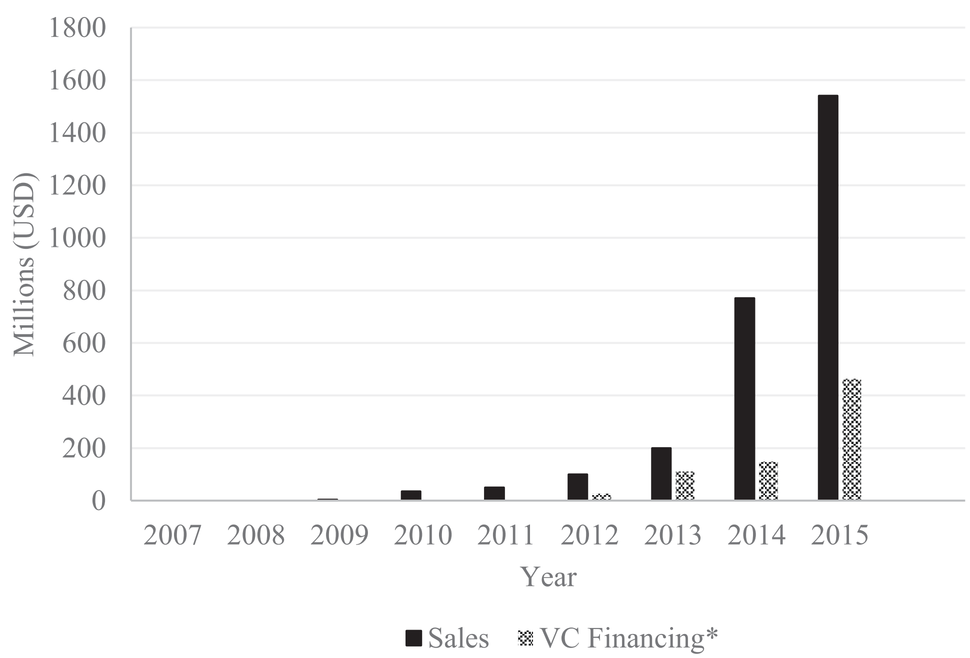
2007	Founding of DIY Drones user community and FIRM
2008	Founding of COMM
	FIRM and COMM introduce first products: flight controller for airplane (COMM) and helicopter (FIRM) architectures
2009	Community members find product architecture problem and quadrotor solution
2010	COMM finds product architecture problem by watching individual experimentation in the community converge on the quadrotor
	COMM solves quadrotor innovation problem using the community designs for quadrotor components
	Two diversifying firms enter civilian drone industry using quadrotor architecture, focusing primarily on children's toy market
	Quadrotor becomes dominant design
2011	FIRM finds product architecture problem and quadrotor solution by chance from a distributor
	FIRM solves quadrotor innovation problem by designing quadrotor components
	Later, both firms recognize large market opportunity and killer app problem. FIRM uses parallel experimentation to explore specific markets
	COMM relies on individual experimentation by community to explore broadly
2012	*Early*
	FIRM finds underlying low-quality video problem
	Community develops many small innovations that benefit members
	Cloners enter
	COMM watches and waits for community to find the killer app
	Mid
	COMM and FIRM find obvious assembly hassle problem
	FIRM uses hybrid problem solving, parallel experimentation with competing teams, rapid serial experimentation to begin RTF drone design
	COMM uses modular problem solving, less coordinated individual experimentation, slow serial experimentation to begin RTF drone design
	Community member develops low-quality gimbal
	Late
	FIRM solves high-quality gimbal innovation problem with new products for new customers in the professional market
	COMM watches community converge on video problem and low-quality gimbal solution
2013	*Early*
	FIRM introduces incomplete RTF drone
	COMM refines the problem and finds underlying low-quality video problem
	Mid
	COMM works with community and then third-party to design gimbal
	Late
	FIRM solves RTF drone innovation problem and introduces complete RTF drone with integrated camera and gimbal
2014	*Early*
	COMM introduces incomplete RTF drone designed with the community
	FIRM continues improving its drone gimbal and RTF drone
	Mid
	COMM goes back to community to design gimbal
	COMM acquires engineering team to design RTF drone
2015	*Mid*
	COMM solves RTF drone innovation and gimbal problems and introduces complete RTF drone with camera and gimbal
	FIRM introduces family of RTF drones (with an improved gimbal) at multiple price points including a comparable one at a lower price than COMM's drone

Figure A.1. Total Number of Civilian Drone Firms



Notes. In 2007–2008 COMM, FIRM, and two other ventures entered and began the market. The latter two remained small and insignificant niche players. COMM and FIRM became the largest and most important firms. In 2010, two diversifying firms entered, initially targeting the children's toy (not hobbyist) market. In 2011–2012, clone manufacturers entered. In 2013–2014, a wave of ventures with professional investment began. Many of these ventures began in or pivoted to software only or a specific vertical within a year or two in light of FIRM's growing dominance. In 2015, later entrants were software or vertical-specific.

Figure A.2. Civilian Drone Market Size (Sales) and VC Financing



Endnotes

[1] Consistent with Puranam et al. (2014), we define organizing form as how an organization defines its internal and external boundaries, such as membership; allocates tasks; provides rewards; and exchanges information, such as open source versus proprietary.

[2] Our reviewers advised pseudonyms to avoid confusion with these similar names.

[3] Two other ventures also began about the same time but remained small and insignificant niche firms. In 2010, two diversifiers entered. In 2011–2012, clones entered. In 2013, the major entry of ventures with professional investment began. See Figure A.1 and Table A.1.

[4] We randomly sampled six members and snowball sampled eight core members who were contributors to the focal innovations. Interviewee demographics: average age = 36, male = 100%, undergraduate degree = 83%, graduate degree = 42%, 50% North America, 17% Europe, 33% Asia/Australia. We also interviewed nine unique executives/investors at COMM and eight at FIRM.

[5] Per "Methods," we assess when COMM finds the problem by when a COMM executive identifies it, not when members identify it.

[6] Per "Methods," FIRM did not participate in or actively monitor DIY Drones or any community. This was the only time that we saw FIRM reference a community design. Even here, FIRM went on to design its own quadrotor innovation, consistent with firm-based organizing.

[7] Hybrid problem solving organizes learning by successively focusing on designing the most critical remaining component while maintaining a holistic understanding of the many interrelationships within the entire innovation. It requires extensive coordination and fits novel, complex problems such as the RTF drone. In contrast, modular problem solving cannot cope with many (i.e., complex), novel (i.e., uncertain) component interrelationships. Integrative problem solving (i.e., keeping all components in mind at once) only works when the innovation has few components such as the gimbal.

[8] At this time, the design of the RTF drone overlapped with the drone gimbal at both firms (Table A.1 timeline).

[9] Research on community–firm relationships indicates that established firms can set up effective innovation relationships with communities in mature markets, such as IBM with Linux, and in nonmarket settings, such as IDEO with OpenIDEO (Nagle 2018a, Lakhani et al. 2020). Yet these relationships are likely difficult to negotiate in nascent markets given their uncertainty and often high-velocity change.

[10] Consistent with Useem et al. (2017), the only distinct features of Chinese business that we saw were "friends and family" on the executive team and closely controlled equity with little equity sharing for employees. If anything, these features seem likely to have held FIRM back.

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