Unveiling Opportunities afforded by Emerging Technologies:

Evidences from the Drone Industry

Stefano Magistretti

School of Management, Politecnico di Milano, Milan, Italy
Tel: +39 02 2399 4093; Fax: +39 02 2399 2720; email: stefano.magistretti@polimi.it

Claudio Dell'Era

School of Management, Politecnico di Milano, Milan, Italy
Tel: +39 02 2399 2798; Fax: +39 02 2399 2720; email: claudio.dellera@polimi.it

In recent decades, researchers and practitioners have increasingly focused on how to develop breakthrough technologies. Notwithstanding this, companies still face the problem of understanding the opportunities enabled by technologies from the early stage of development. The technology management literature highlights that development is usually managed by adopting one of two approaches: normative or explorative. However, in using the latter approach focused on developing emerging technologies, unanswered questions remain. In particular, this paper aims to shed light on the strategies that companies adopt to unveil the opportunities enabled by emerging technologies. Analysing the drone industry using an exploratory case study approach, we investigate the strategies that companies implement to guide technology development to address more meaningful application fields. Using the Federal Aviation Administration database, we identify four possible strategies to develop emerging technologies: focus, deep, broad, and holistic.

Keywords: technology development, unlock opportunities, technology epiphanies

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Introduction

We live in a world where the challenge is no longer generating meaningful new ideas, but selecting the most valuable ones. The so-called paradox of choice that Schwartz proposed in 2004 as a driver of the purchasing process is also becoming relevant in several research fields. Academics and practitioners recognize the need to understand how to identify the meaningful ideas and technologies from the large number available to their organizations (Verganti, 2017). Although in the last decades several emerging and relevant innovation methodologies, such as crowdsourcing and hackathons, focus on the ability to creatively generate several ideas (Howe, 2006; Brabham, 2008), in a world full of technological opportunities, the crucial challenge is increasingly the ability to recognize those few solutions that are meaningful to people (Verganti, 2017). Indeed, researchers have highlighted that innovation projects can no longer be managed through a traditional and constrained stage-gate approach, and that such methodology is more useful in dealing with uncertain projects (Cooper and Sommer, 2016).

The rich literature on technology development proposes two different approaches in the exploration of opportunities enabled by emerging technologies: normative and exploratory (Twiss, 1992). The first approach suggests initially identifying the future and desired application, and then looking backward to identify the development phases required to improve the underlying technology (Dreborg, 1996). Alternatively, the second approach aims at defining a more tentative strategy based on the search for future applications of the technology by leveraging its different intrinsic and extrinsic elements (Kahn, 2002). However, when the aim is to unveil opportunities hidden in the technologies, studies advocate the technology epiphany approach, defined as the sudden revelation of quiescent meanings within a technology (Verganti, 2009). Differently from the normative and explorative approaches, this approach is aimed at unveiling the quiescent meaning hidden within a technology by offering a new driver for adopting such technology (Buganza et al., 2015; Dell'Era et al., 2017; Trabucchi et al., 2017).

Practitioners and scholars therefore seek to enrich current knowledge on how to unveil meaningful applications in emerging technologies by understanding how to steer technology development ex-ante instead of recognizing it ex-post. Hence, our study analyses how companies can develop technologies by unveiling opportunities hidden within emerging technologies in developing meaningful applications.

Considering our aim and the "how" question, we adopt a case study methodology focusing on an inspiring and underexplored industry: the drone sector. Indeed, this setting is ideal for at many reasons. First, drone technology is still under development, and will be for the next 5 years, as reported in the Hype Cycle of Gartner 20171. Second, it can be considered an emerging technology (Rotolo et al., 2015) due to its rapidly growth and huge impact on the market, as reported by Business Insider showing a growth by 150% in the next five years[2]. Finally, since its first introduction in the military, this technology has huge potential for future applications in different industries. Analysing the Federal Aviation Administration (FAA) database, we show that companies develop emerging technologies based on three different dimensions: technology development breadth, depth, and driver. First, breadth concerns the dimension related to the application fields in which the technology is applied. Second, the depth dimension concerns the variety of technological solutions explored. Finally, the driver dimension examines the reason (i.e. function or meaning) for adopting a technology. We therefore label the different strategies as: (i) focus, (ii) deep, (iii) broad, and (iv) holistic.

The article is structured as follows. The next section provides a review of the relevant technology development literature. Thereafter, we present the methodology adopted in this

[1] https://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017/
[2] http://www.businessinsider.com/the-drones-report-research-use-cases-regulations-and-problems-2017-9?IR=T

study, assess the empirical results, and offer a discussion and some conclusions. The final section summarizes the limitations and potential future research avenues.

Technology development literature review

The literature on technology management is vast. Given our aim of understanding how companies unveil opportunities hidden within emerging technologies, we review mainly contributions related to technology development. The theoretical reasoning underlying the selection of this field is linked to the fact that research in technology management highlights primarily two different phases (Cooper, 2006): selection (Cuhls, 2003;) and development (Van de Vrande et al., 2011). The literature on selection reports the different processes that allow companies to choose a technology from those available (Krishnan and Bhattacharya, 2002; Eto, 2003). Despite the relevance of this technology management phase, this is not the focus of our study, as the technology in question already exists (drone), and hence our focus on the technology development literature. Technology development is the phase that occurs just after selection and is characterized by the exploration of the technology (March, 1991) to identify where it can be integrated into meaningful applications (Iansiti, 2000).

Technology development process

Worth noting is that also in technology development, adopting a different sequence of phases allows companies to devise new technological solutions. A first example is development through experimentation (Thomke, 2003). In such case the technology is iteratively defined and tested with the aim of understanding the main features and the performance of the technology that can foster innovations in different application fields (Hegger et al., 2007). As evident, this development process usually entails the repetition of similar phases along the R&D process. Experimentation can be influenced and managed through the different combination of existing solutions or technological features to give rise to new technologies (Schumpeter, 1939; Cohen et al., 2012). Researchers define this process as search and recombination (Natalicchio et al., 2017; Savino et al., 2017), since to innovate, companies search and recombine existing knowledge elements (Schilling and Green, 2011).

A different perspective to experimentation is the linear view of developing the technology. Accordingly, the S-shaped curve shows that the development of a technology follows a linear evolution after achieving a particular performance over its lifecycle (Christensen, 1997; Foster, 1986; Utterback, 1994). Notwithstanding this, scholars point out that this theorized smooth evolution of technology is not linear but more irregular (Sood and Tellis, 2005), and influenced by the ecosystem (Adner and Kapoor, 2016), testifying to the emergence of more dynamic perspectives of unveiling opportunities in technology.

Regarding the technology development process, scholars outline some key elements at the firm level that influence the evolution of a technology (Chiesa, 2000). Just to mention one, they point out a set of capabilities that can deeply influence technical developments (Cohen and Levinthal, 1989). Furthermore, heterogeneity in the demand side can affect technology development both in the early and later technology evolution stages (Adner and Levinthal, 2001). Moreover, Levinthal (1998) shows that technology development can be guided by speciation the use of existing know-how to guide development in addressing a different domain through a better understanding of the main functionalities a technology offers.

Approaches in technology development: normative, explorative, and epiphany

Moving to the different approaches to technology development, the literature reports that this can take place in a normative, explorative, or epiphany way. In particular, the normative approach occurs when after selecting the technology, development starts from the future application field where the technology will be implemented and backcasts to the steps needed to reach that end point (Dreborg, 1996). Figure 1 schematically shows this technology development approach and how the normative approach already envisions the first application field in which the emerging technology will be introduced. Given the uncertainty and complexity pertaining to this phase (McGrath and MacMillan, 2009), the normative approach reduces the risks by leveraging the intrinsic aspects of the technology and understanding where the technology can be successful (Danneels and Frattini, 2018).

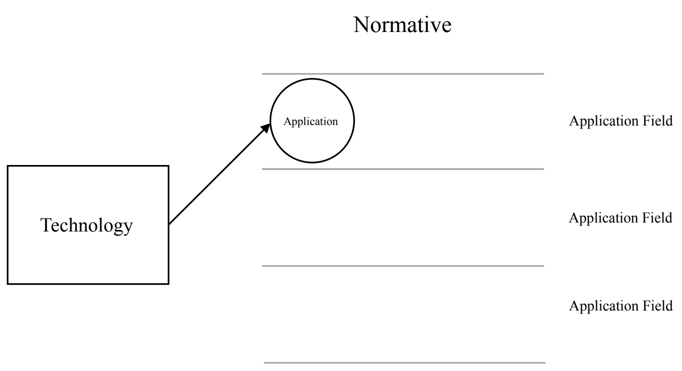

Figure 1. Normative technology development approach

The second approach is the explorative, which is less prescriptive and defined. It usually starts from the present and the search for future application fields by leveraging tests performed during the exploration of the technology (Kahn, 2002). The explorative approach cannot be considered a linear approach connoted by stages and gates (Schmoch, 2007). Grodal et al. (2015) highlight that the technology development process is a combination of divergent and convergent phases, and not only a funneling process (Twiss, 1992). Indeed, the evolution of methodologies such as stage-gate (Cooper, 1994) into agile methodologies (Cooper and Sommer, 2016) shows that the current perspective on how to manage innovation is moving from something normative to something more dynamic. Figure 2 shows the key essence of the explorative technology development approach.

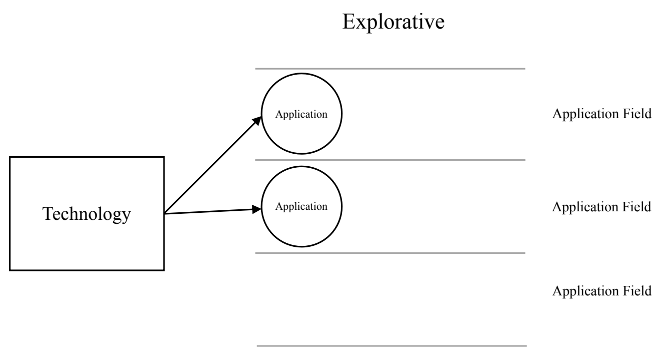

Figure 2. Explorative technology development approach

Moreover, when the technology is emergent and hence characterized by particular aspects (Rotolo et al., 2015), such as rapid growth and uncertainty, researchers stress the relevance of the explorative approach (Fleming, 2001; Weng et al., 2014). This allows R&D departments to learn and advance in the development (Thomke, 2003; Hegger et al., 2007). Moreover, through exploration firms can unlock the latent value of the technology (Adner and Levinthal, 2001; Chesbrough, 2003).

In addition to the normative and explorative technology development approaches, researchers have recently highlighted that the unveiling of hidden opportunities in technologies can be a valuable driver of technology development. This approach is defined as a technology epiphany (Verganti, 2009), implying that the technology offers more, albeit finite, opportunities than those envisaged by early adopters (Verganti, 2011; Trabucchi et al., 2018). The ability to appropriately manage technology development to capture these opportunities is a crucial aspect for practitioners and academics, considering that technology epiphanies have thus far not been deeply explored. As researchers show, this can occur through the normative as well as the explorative approach. Figure 3 reports the underpinning elements of this approach. Indeed, an epiphany does not usually occur in a linear and smooth process (Verganti, 2009), tending to be rather segmented (e.g., MEMS technology in the Nintendo Wii Dell'Era et al., 2017).

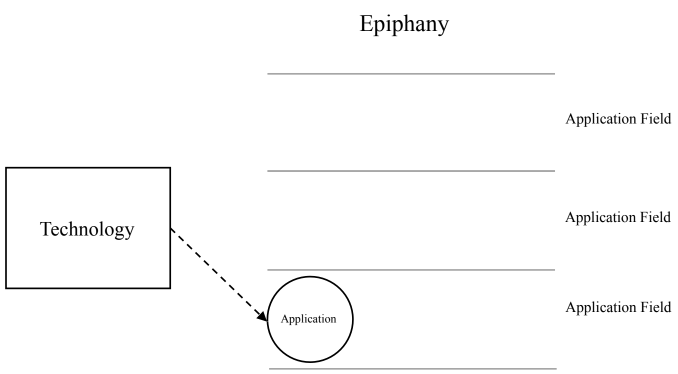

Figure 3. Epiphany technology development approach

Emerging from the technology development review is the ongoing debate and growing scholars' attention to new approaches to better guide technology development in unveiling hidden opportunities. This is the theoretical foundation of our study and leads to the following research question: how can companies unveil the opportunities afforded by emerging technologies by developing them in meaningful application fields?

Research design

Our investigation aims to enhance knowledge on emerging technology development strategies. A brief explanation of two key concepts is called for prior to detailing the methodology adopted in this study. Using the aforementioned technology epiphany definition (Verganti, 2011), meaningful application fields are intended as market sectors where the economic and non-economic value is higher compared to other industries. The second specification concerns Rotolo et al.'s (2015) definition of emerging technology encompassing five key aspects: radical novelty, relatively fast growth, coherence, prominent impact, and uncertainty.

Research methodology

Our research objective is to provide a better understanding of how companies explore opportunities during technology development. Thus, we selected the emerging and innovative drone technology as the most relevant to enrich our knowledge. We use an exploratory case study approach, considered the most appropriate methodology to answer "how" questions (Eisenhardt, 1989), and investigate complex phenomena (Yin, 2003). The selection of cases is a crucial aspect of such methodology (Siggelkow, 2007). As the literature review shows, knowledge on this topic is still evolving, and a univocal view on the technology development is still lacking.

Empirical setting

The empirical setting is fundamental from both a theoretical and managerial perspective (Siggelkow, 2007). As such, we selected the drone technology to shed light on this topic, corroborated by the fact that this is an emerging technology (Rotolo et al., 2015). Indeed, drone technology is radically new, relatively fast growing, and uncertain in the future. According to Gartner's 2017 Hype Cycle3, drone technology is still under development and will be for the next 5 years. Moreover, it is evident that the development of drone technology follows both an explorative (Khan, 2002) and normative approach (Dreborg, 1996). Looking at different application fields with different perspectives enables better understanding how hidden opportunities can be unveiled. From the practitioner perspective, we selected the drone industry due to the increasing investments and the growing number of different applications launched.

In particular, we investigate a specific type of drone, Unmanned Aerial Vehicles (UAV), the most pervasive drone in today's market. Business Insider reports that revenues from drone sales should reach $12 billion by 2021, today standing at around $8 billion. Given

[3] https://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017/

this expected growth and that this technology will be progressively used in several different industries ranging from the military to other civilian sectors, a deeper understanding of this field is pertinent to practitioners and researchers alike.

Data collection and analysis

To investigate the evolution of the drone technology during its development, we use the FAA database. Even if this is a simplification of the reality due to the fact that it addresses just the US Market, its trustworthiness provides a solid starting point. This database encompasses all companies that have requested formal permission to use UAV in a real work context. In addition, we researched the petitioners to create a unique database with information on the companies that have adopted and integrated the technology in the market. In particular, our starting point was creating a database of the 5,552 exemptions granted, a formalization of the FAA website. This initial database was than analysed to better comprehend the development dynamics. In particular, three different researchers undertook a first analysis of the database and individually read all the petitions to identify a subset of relevant application fields in which exemptions were requested. Starting from the 5,552 different operations and missions present in the database, we were able to identify a final subset of 18 relevant and homogeneous application fields.

After identifying the 18 relevant application fields for each of the 5,552 petitions, the application fields included in the exemptions requests were inserted in the database. Considering a single company could have requested an exemption for more than one application field at a time, we rearranged the database by application field, thus enlarging the database to 7,754 lines. Figure 4 reports the temporal distribution of the exemptions granted by the FAA in each application field in the period September 2014 - March 2016. This is due to the fact that in September, the first exemption was granted, while after March, due to a change in regulations, the number grew exponentially.

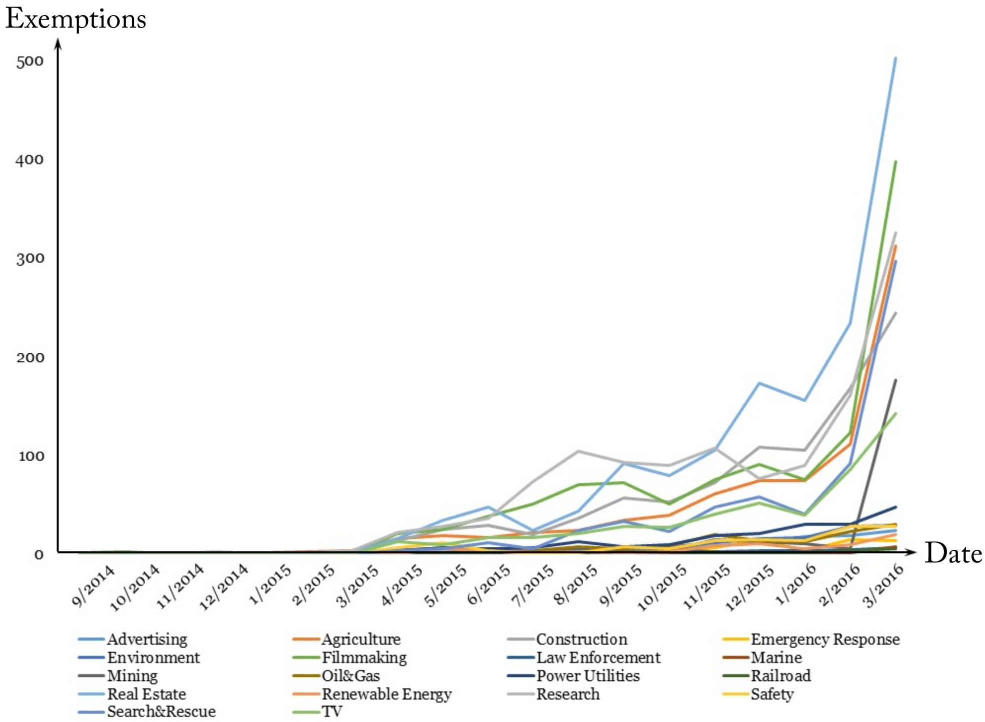

Figure 4. Temporal distribution of exemptions granted by application field

We therefore analysed the petitions in relation to the 18 application fields previously identified. Given our focus on the development strategy, we considered the first petitioner in each application field to understand how companies explore the opportunities hidden within the drone technology. The reason for focusing on the first petitioners is twofold. First, as previously explained, the complexity of the investigation required adopting a case study methodology, and we deemed these companies exemplary and insightful for our research purposes, a fundamental prerequisite for the success of such methodology (Siggelkow, 2007). Second, by being the first to explore the opportunities enabled by drones, the companies provided significant insights on how they approach such an emerging technology in addressing a new application field (Rotolo et al., 2015).

The analysis of the 18 pioneers in adopting the drone technology in new application fields is based on three indicators that allowed us to identify the underpinning elements that guided the different developments undertaken by the companies. The first, depth of technology development, measures the number of different UAV models adopted by the petitioners as a proxy of the number of technological solutions explored by the companies (Sood and Tellis, 2005). The second indicator, breadth of technology development, is a proxy of how many application fields a company approached with the emerging technology to provide insights on the willingness to explore the solution in different contexts (Iansiti, 2000). The third, driver of technology development, stands for the reason the petitioner developed the drone technology. In particular, the literature shows this can be guided by reason of function or meaning (Verganti, 2009).

Empirical Results

To answer our research question, we focused on the exemplar cases of technology adopters who first adopted a strategy to explore the opportunity afforded by the drone technology in a particular field. Table 1 reports the 18 cases with the associated application fields where they operate.

Table 1. Application fields and related first adopters

Application field	**Case Studies**
Advertising	Hovershots APV
Agriculture	Advanced Aviation Solutions
Construction	Bechtel Equipment Operations
Emergency Response	Aerologix Consulting
Environment	Toledo Aerial Media
Filmmaking	Aerial MOB
Law Enforcement	Advanced Robotics Corporation
Marine	FalconSkyCam
Mining	EnviroMINE
Oil&Gas	VDOS Global
Power Utilities	Commonwealth Edison Company
Railroad	BNSF Railway
Real Estate	Douglas Trudeau

Renewable Energy	Notus Access Group
Research	Woolpert
Safety&Security	Jackson Family Wines
Search&Rescue	Down East Emergency Medicine Institute
TV	Upward Aerial

For each of the 18 cases, we collected information on the number of application fields addressed with the exemption, the number of exemptions requested in the 2014-2016 period, and the types of UAV models included in the exemptions[4]. This information allowed us to understand how the companies developed the emerging technology. Indeed, when a company was granted an exemption for several UAV models, the depth of development is considered high, since by adopting several models, the company explores the opportunities the drone technology offers through experimenting with different uses. On the other hand, the different application fields for which the petitioners requested exemptions indicate the breadth of technology development as a proxy of how many application fields they addressed. In addition, we mapped the reason why the companies developed the technology with particular breadth or depth. This allowed us to add a new level of evidence related to the fact that the firms adopted the UAV technology guided by a meaning or function perspective. To do so, and in accordance with the literature (Verganti, 2011), we did not consider the first company adopting the drone technology, as the literature shows that the meaning or function perspective can only be evaluated by comparing the adopters with the previous ones. We performed this further analysis by considering the operations as well as the missions indicated in the petitions and surveying the websites of the 18 cases. For instance, integrating drone technology in the agricultural or marine sector enables unveiling a real, tangible, and meaningful application for the emerging technology. Using this key information, we classified the 18 cases along the three dimensions reported in Table 2.

[4] Please refer to Annex section A for further details on the data gathered.

Table 2. Technology development Breadth, Depth, and Driver

Cases	Breadth of technology development (number of application fields)	Depth of technology development (number of UAV models)	Driver of technology development (source of competitive advantage)
Hovershots APV	2	1	Function
Advanced Aviation Solutions	6	12	Function
Bechtel Equipment Operations	1	1	Meaning
Aerologix Consulting	3	1	Function
Toledo Aerial Media	4	2	Meaning
Aerial MOB	3	6	N.A.
Advanced Robotics Corporation	4	2	Meaning
FalconSkyCam	3	1	Function
EnviroMINE	1	1	Function
VDOS Global	1	1	Function
Commonwealth Edison Company	1	1	Function
BNSF Railway	1	3	Function
Douglas Trudeau	1	1	Meaning
Notus Access Group	1	1	Function
Woolpert	2	1	Function
Jackson Family Wines	1	1	Function
Down East Emergency Medicine Institute	1	2	Function
Upward Aerial	2	1	Function

]

Here we briefly report two examples of the analysis performed over the 18 cases..

The first case is AeroLogix Consulting, a company founded in 2007 that asked permission to adopt UAV in April 2015. In particular, the company requested permission to use its own manufactured drone AeroLogix GeoStar (see Figure 5) for aerial surveying to produce imagery and terrain modelling for three different sectors: emergency response, environment, and agriculture.

Figure 5. AeroLogix GeoStar UAV

The analysis of the case also allowed us to schematize the development process that AeroLogix adopted on the three breadth, depth, and driver dimensions of technology development. Indeed, the company asked permission to adopt just one drone, so the depth was limited to one, while the breadth was higher since it introduced it in 3 different application fields, albeit with the same function: scan the landscape and collect photos. Thus, the approach can be deemed explorative rather than normative. Figure 6 shows how AeroLogix explored the technology by simultaneously introducing the UAV model in three application fields.

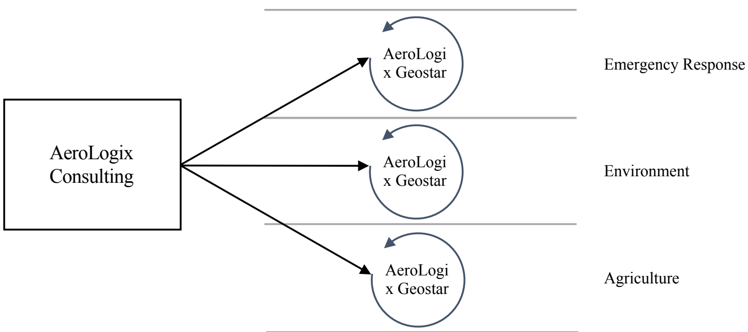

Figure 6. AeroLogix breadth, depth and driver of technology development

The second case we report in this section is Toledo Aerial Media, as it constitutes an inspiring case of technology development that leverages the three dimensions differently than the previous case. In particular, in April 2015, the American company asked permission to develop the adoption of two UAV models to record more meaningful videos of wildlife. Clearly, the reason for asking permission is less functional and more meaningful, since the end results would enable conveying a completely different image of the natural environment to the market and obtaining better live images for documentaries. Figure 7 reports the two drones the company adopted in wildlife monitoring and in another three application fields. Figure 8 shows the approach the firms adopted in exploring technology development in a technology epiphany approach.

Figure 7. UAV models within the Toledo Aerial Media exemption

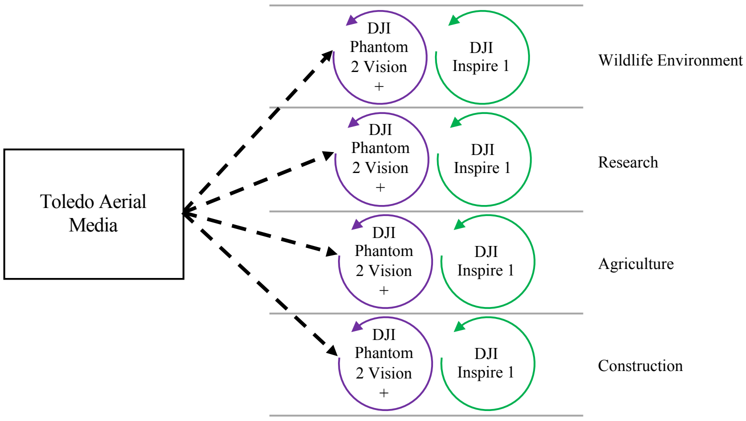

Figure 8. Toledo Aerial Media technology development breadth, depth, and driver

Discussion

The results of the analysis show that the 18 exploratory case studies have particular characteristics that allow identifying different technology development approaches. Specifically, we outline the main traits and the choices the companies made to explore the UAV technology. By considering the technology development breadth, depth, and driver dimensions, we identified 8 groups. Indeed, from comparing and contrasting the cases, different technology development approaches emerged. Figure 9 summarizes the cases on the three dimensions.

Depth of Technology Development	Normative (Application Field=1): Functional	Normative (Application Field=1): Meaning	Explorative (Application Field>1): Functional	Explorative (Application Field>1): Meaning
High (Number of UAV models>1)	• BNSF Railway • Down East Emergency Medicine Institute		• Advanced Aviation Solutions	• Advanced Robotics • Toledo Aerial Media
Low (Number of UAV models=1)	• Jackson Family Wines • Notus Access Group • Commonwealth Edison Company • VDOS Global • EnviroMINE	• Bechtel Equipment Operations • Douglas Trudeau	• APVFalconSkyCam • Aerologix Consulting • Upward Aerial • Woolpert • Hovershots	

Breadth of Technology Development

Figure 9. Case studies mapped according to technology development depth, breadth, and driver

Figure 9 shows that the companies approached technology management from different perspectives. Indeed, a company addressing a single application field implies that it seeks to maintain its current business. On the other hand, firms experimenting with different technologies show a greater risk-taking propensity, exploring different configurations of the technology to unlock hidden opportunities (Bingham et al., 2014). Four possible strategies to developing the technology emerge from analysing the positioning of the cases on the matrix in Figure 9 depending on whether they address a single industry or not, and whether they adopt one UAV model or more. Accordingly, the four different strategies are: focus, deep, broad, and holistic. These four strategies are then characterized by the fact that the firm adopts them to convey a meaning or a functional use of the technology to the market see Figure 10.

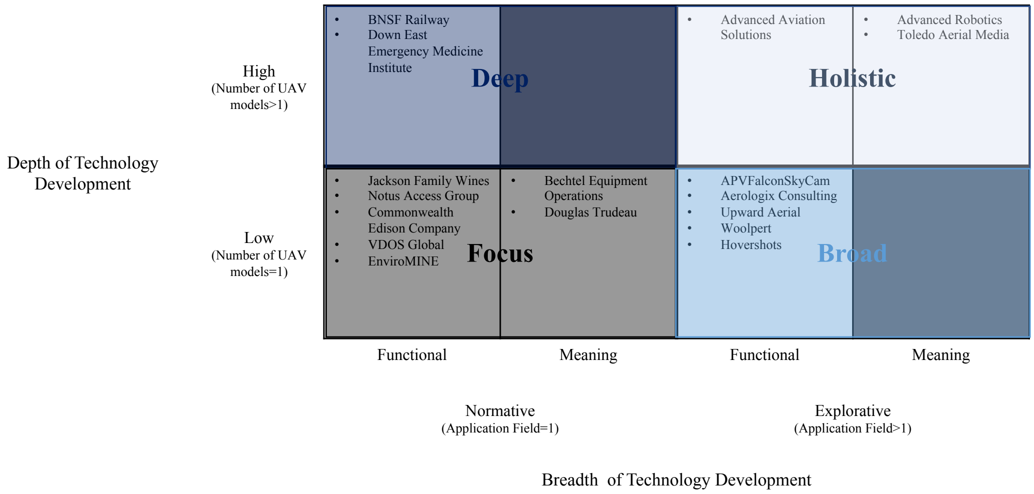

Figure 10. Technology development strategies

The distribution of the firms in the four strategies shows that more than 50% are positioned in the focus or holistic groups. This interesting evidence highlights that firms developing emerging technologies leverage all three strategies, even if in different combinations, and their higher risk-taking propensity (Ryall and Samspon, 2009), since they do not invest in one model and one industry but take greater risks by developing the technology in different application fields and/or models.

We now provide a detailed overview of the different strategies. The first is *focus*, limited to a single new industry, without expanding into other industries or further deepening the chosen industry. Referring to drone technology, firms adopting this strategy opted for a single UAV model to improve their performance within their respective industries. Thus, their risk-taking propensity and willingness to explore are not high even if the underlying driver of technology development relates to both function and meaning.

The second is the *deep* strategy. In this case, the choice of focusing on a single industry is reinforced by further commitment. Two firms adopted the normative technology development approach. This group is less populated and can be explained by the fact that adopting this strategy usually implies a certain level of confidence and experience in a single industry. The fact that the depth strategy adopters are firms that are leaders in their industries and adopted a larger variety of UAV models implies a more advanced development strategy compared to the focus approach. To reinforce this sense of belonging to an industry, the technology development driver is only one of function in this strategy.

The third is the *broad* strategy, where the focus is extended to a greater number of industries in which the technology is explored. This strategy can lead to lower exploration of the technology itself, as they do not adopt more than one UAV, but greater propensity to explore the adoption of the technology in different markets. Nevertheless, by exploiting their knowledge of the single models, they seem to be unable to change the technology development driver from function to meaning.

The last is the *holistic* strategy. In this case, companies opt to address multiple industries where selection is developed on an ongoing and wider basis. Indeed, the choice of exploring new solutions evolves over time and requires adopting different models of the emerging technology. When addressing other industries, companies adopting this approach do not restrict the number of models adopted and prefer a broader set of available technologies to explore so as to better understand the emerging technology. Adopting this strategy allows firms to convey both function and meaning to the market. The latter enables grasping the opportunities offered by the technology through exploring a broad set of application fields, which can lead to a higher probability of unveiling hidden opportunities in the technology.

This discussion suggests the following three propositions:

Proposition 1: In developing emerging technologies, the greater the breadth of application fields addressed, the higher the likelihood the firm will unveil hidden opportunities within the technology.

Proposition 2: In developing emerging technologies, the greater the depth of technology applications addressed, the higher the likelihood the firm will unveil hidden opportunities within the technology.

Proposition 3: In developing emerging technologies, the more equal the presence of both breadth and depth, the higher the likelihood the firm will discover a field where the technology is more meaningful.

The four strategies and the three propositions indicate the firms' approach to an emerging technology to understand the opportunities it offers. Studying the drone industry, this investigation enriches knowledge on the topic of emerging technologies (Rotolo et al., 2015) from different perspectives. Indeed, as several researchers highlight, these types of technologies have assumed increasing relevance for their perceived ability to change the status quo (Cozzens et al., 2010). Moreover, looking at the industry level, and understanding how companies unveil the opportunities provided by the technology, the cases studied show that firms approaching an emerging technology do not merely substitute older technology but they attempt to understand the meaning of the emerging technology through developing it in both the breadth and depth dimensions (Dell'Era et al., 2017).

Theoretical and Managerial Implications

The main contributions of our study are both theoretical and practical. Starting from the theoretical contribution, by qualitatively exploring the four strategies, some insights emerge on how companies can unveil the opportunities a technology offers. Hence, firms seeking to learn more about an emerging technology should adopt mainly the focus and holistic strategies. Exploring technology in a more structured way enables gathering information that can help unveil the quiescent meanings hidden within the technology. The definition of the four strategies contributes to the technology development literature, furthering our knowledge on emerging technologies. Indeed, the different approaches to adopting drones in an industry enable exploring the technology in a more structured way compared to the linear funnelling approach (Twiss, 1992). This constitutes a more planned and formalized way of identifying the opportunities the technology offers than traditional learning-by-doing (Lapré and Van Wassenhove, 2001).

Moreover, it contributes to that literature by showing that technology exploration can follow three dimensions: the technological (depth), the market (breadth), and the underlying motivation (driver) (Bahrami and Evans, 1989; Becker et al., 2005; Verganti, 2009). Second, the investigation conducted enriches knowledge on the broader technology development process according to the emerging trend rooted in the agile approach (Cooper and Sommer, 2016). Technology exploration in both the breadth and depth dimension cannot be considered as subsequent linear phases but entail continuous iterations. Figures 6 and 8 emphasize these aspects by pointing out that firms can address one or more industries, and when drones are introduced in such industries, the evolution of the technology advances through continuous exploration, as the arrow around the name of the drone in these figures indicates. This exploration view of technology development enriches our knowledge in relation to the traditional approach (Cooper, 1994) where milestones are positioned between the two phases, superseded by the notion that the experimentation and integration process is not only divergent and convergent (Grodal et al., 2015), but simultaneous. Exploring technology enables identifying potential new uses in different industries, entering these as first movers and deriving the consequent advantages. Conversely, expanding the exploration breadth to different industries may lead to different technical solutions and consequently improving what is currently done. Third, our belief that R&D is no longer the dominant design in creating and shaping new technologies is corroborated (Christensen, 1997; Snow et al., 2011), while direct exploration in the field allows grasping and understanding the value of the technology. In turn, greater risk-taking propensity is more likely to lead to unveiling the opportunities the technology offers and unlock its latent value (Chesbrough, 2003), particularly when experimenting and integrating the technology in a holistic approach.

Finally, this investigation enriches knowledge in the search and recombination literature (Savino et al., 2017) by showing how in adopting the four strategies firms can recombine knowledge coming from the three dimensions of breadth, depth, and driver.

Regarding the practical implications of the investigation, our study contributes to enriching knowledge of high-tech companies and practitioners dealing with technology development. First, our study shows that technology development can be influenced by three different dimensions: depth, breadth, and the driver of technology development. Thus, companies dealing with an emerging technology can approach its development with four different strategies: focus, deep, broad, and holistic. Second, our study shows that the three dimensions are combined and explored to increase the probability of unveiling more opportunities hidden within the technology, as illustrated in the matrix. Finally, we highlight the fundamental role of risk taking in the development process. Specifically, the probability of discovering the opportunities the emerging technology offers is higher when firms embrace more risk.

Conclusions

Using a unique database of FAA exemptions granted to companies for using UAV in the US market, this paper identifies four technology development strategies that can guide companies in developing an emerging technology. The first is the focus strategy that describes companies that remain focused on their core industry and explore with just a single drone solution. The second, the depth strategy, describes companies that explore a greater variety of solutions for a single technology. The third, the breadth strategy, categorizes firms that explore the emerging technology in different industries. Finally, the holistic strategy incentivizes companies to identify more meaningful application fields and explore a variety of solutions. In summary, to discover new opportunities hidden within an emerging technology and address new meaningful application fields, firms adopt mainly two approaches among the four focus and holistic, and particularly an equal level of breadth and depth.

In terms of the study's limitations, due to its exploratory nature, we were unable to measure the impact of the different strategies on the economic performance of firms. Furthermore, the selection of cases and the US market limit its generalizability. However, these limitations open the way for future studies in a wider domain, including the traits characterizing different environments (e.g., different regulatory frameworks, technology availability, specific competencies) that may affect the approach that companies pursue when exploring and experimenting emerging technologies. Furthermore, future investigations could focus on the entire model or exclusively on specific approaches in the same or in different industries, as well as adopting more refined and quantitative methodologies.

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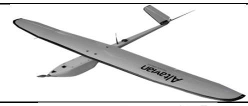
Annex A:
Table 3. Detailed information on the 18 case studies

Firms	Exemption date[5]	Operation/ mission	First industry inserted in the exemption	Other industries inserted in the exemption	Number UAV models	Picture of the drone
Hovershots APV	04/2015	Aerial photography for the media and advertising industries	Advertising	TV	1. Steadydrone QU4D	
Advanced Aviation Solutions	01/2015	Aerial surveying and mapping, and UAS instruction	Agriculture	Research Environment Real Estate Filmmaking Advertising	1. SenseFly eBee 2. 3DRobotics Aero-M 3. 3DRSolo 4. SteadiDroneFlare 5. SteadiDrone Mavrik 6. DJIMatrice 100 7. DJIs1000 8. DJIS900 9. DJIInspire1 10. DJIPhantom3 11. DJIPhantom2 Vision 12. DJIPhantom2	
Bechtel Equipment Operations	04/2015	Aerial imaging in construction operations	Construction		1. Skycatch	

[5] For more information on exemptions, see https://www.regulations.gov/searchResults?rpp=25&po=0&s=Section%2B333%2BFAA&fp=true&ns=true

Aerologix Consulting	04/2015	Aerial survey to produce imagery and terrain modeling products useful in applications ranging from water resource management, environmental research, disaster response, agriculture	Emergency Response	Environment Agriculture	1. GeoStar	
Toledo Aerial Media	04/2015	Aerial surveying, remote sensing, photography, agricultural, construction, and wildlife monitoring	Wildlife Environment	Research Agriculture Construction	1. DJIPhantom2 2. DJI Inspire1	
Aerial MOB	09/2014	Closed-set filming	Filmmaking	TV Advertising	1. AerialMOB Hexa-copter 2. HexaCrafter HC-1100 3. Aeronavics SkyJib8 Heavy Lifter 4. AerialMobDiscoveryPro LightLifter 5. A.M.Halo8 HeavyLifter 6. DJIPhantom2	

Advanced Robotics Corporation	06/2015	Education and training, aerial survey /inspection and imaging, agricultural, forestry, wildlife preservation, law enforcement, and search and rescue	Law Enforcement	Research Agriculture Environment Search & Rescue	1. AdvancedRobotics–960 2. Advanced Robotics540	 
FalconSkyCam	03/2015	Aerial photography for real estate, surveying, marine photo and video, agriculture, and special events	Marine	Real Estate Agriculture	1. DJIPhantom	
EnviroMINE	03/2015	Surface mining	Mining		1. SenseFly eBee	
VDOS Global	12/2014	Flare stack inspection	Oil & Gas		1. AeryonSkyranger	
Commonwealth Edison Company	02/2015	Electric transmission and distribution utility system monitoring, powerline inspections, and damage assessments	Power Utilities		1. DJIInnovationsS900	

BNSF Railway	03/2015	Evaluation and analysis of railroad infrastructure and operations	Railroad		1. AirRobot AR180 2. AR200 3. 3DRoboticsSpektre	
Douglas Trudeau	01/2015	Real estate photography, videography	Real Estate		1. DJIPhantom2 Vision	
Notus Access Group	03/2015	Aerial inspections of wind turbine blades and towers	Renewable Energy		1. InstantEyeMk-2	
Woolpert	12/2014	Precision aerial surveying	Research	Safety & Security	1. AltavianNovaBlockIII	
Jackson Family Wines	04/2015	Surveillance over private property	Safety & Security		1. AirCoverQR-425 2.	
Down East Emergency Medicine Institute	04/2015	Aerial search and rescue operations	Search & Rescue		1. VK–FF–X4 2. VK-Ranger EX–SAR	
Upward Aerial	04/2015	Aerial photography and videography for television and commercial videography	TV	Filmmaking	1. DJIT600Inspire1