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New Forms of Engagement in Third Mission Activities: A Multi-Level University-Centric Approach

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Abstract

Traditionally, universities have had two missions: to carry out teaching and research. While the universities still follow these missions, a third mission was added some time ago: university research must establish its direct value for society more clearly. However, a lingering question is how this third mission should be carried out. While the earliest models focused on the universities operating similarly to an R&D department in a private company – seeking to patent as much of the research inventions as possible and then capitalising on the intellectual property rights – the focus today is much more nuanced and incorporates both invention and innovation-oriented activities. This article captures existing knowledge of universities' third mission activities by identifying five different models of how universities seek to fulfil the third mission. These models are empirically investigated through two multi-level case studies based on insights from top management, innovation and/or technology transfer offices, and research units within the emerging drone technology area. The findings illustrate how the two universities seek to fulfil the third mission, based on the same starting point but following different models. The findings identify a sixth model, namely the Ecosystem Model. In this model, the universities engage more extensively and with greater responsibility in simultaneous collaborative efforts with a range of both public and private actors on addressing continuous and comprehensive industrial and societal challenges through technology development and market insights. In doing so, the university's role becomes more active in advancing the development of an industry. This emerging way of addressing the third mission is discussed with respect to university management, achievement of the SDGs and Grand Challenges leading to the formulation of avenues for future research.

Keywords: Drones, research, scientific discovery, technology transfer, third mission, universities, ecosystem, sustainable development goals.

Introduction

The perception of the university as an *ivory tower* (H. Etzkowitz, Webster, Gebhardt, & Terra, 2000), which as an isolated giant exclusively focuses on research and teaching (and the cross-fertilisation between these two missions), has increasingly been challenged (Cesaroni and Piccaluga, 2016). Universities are now being understood and evaluated as a core actor in value creation serving societal needs. The defining principle is that scientific discoveries originating in the research mission hold potential value for external actors like firms, industry, or society at large, and are brought to life through spin-outs, licences, innovations, job creation, etc. These disparate activities have largely been subsumed under the heading of *the third mission* of universities (Geuna and Muscio, 2009). Policymakers see a potential in seeking to capture societal benefits from public investments in research, and therefore attempt to formulate and implement policies that stimulate the university, as a collective actor, to engage in relevant research and innovation activities. At the same time, the universities respond to the public appeal for delivering research with high societal value by developing and pursuing new forms of engagement.

The European Commission seeks solutions addressing Grand Challenges through its Horizon2020 research programmes, and the UN has agreed on 17 Sustainable Development Goals (SDGs). These larger societal purposes pivot the traditional university research and knowledge push towards a mission-driven demand for knowledge and solutions. This outside-in perspective on universities as the sources of solutions for the Grand Challenges and to deliver on the SDGs stimulates a thickened perspective on the requisite research output calling for cross-disciplinary solutions. Consequently, the single university may change its perspective towards a more balanced view of the three missions, i.e. teaching, research and societal impact or outreach; and also from strictly

focusing on technology transfer as an activity that takes place at the level of the university towards the separate contributions of and interactions between research units (researchers, research groups, departments), regions, industry and firms.

The thickened perspective and the outside-in demand for solutions may stimulate the university to reconsider the nature and strengths of its technology transfer and commercialisation capabilities. A plethora of models has emerged for commercialisation and engagement from the well-known Stanford model of licensing out inventions and patents to collaborative research, and networking with practitioners (Geuna and Muscio, 2009; Perkmann et al., 2015). These models are aligned with the perspective of (Benneworth, Pinheiro, & Sanchez-Barrioluengo, 2016, p. 35), who state that

...universities are enormously complex entities that perhaps can better be understood as a range of knowledge-producing communities that are held together within a single institutional framework.

Therefore, the emerging models underline that third mission activities are not taking place at the university level by one uniform actor serving on the basis of a collective whole, but are carried out by a multitude of individual researchers and organisational entities, in different tempi and loci; some more oriented towards revenue from single inventions; some towards access and use of laboratory facilities for research purposes; and yet others towards networking and knowledge sharing with industrial partners. Hence, the body of commercialisation models to encompass the overall ambitions and intentions of the third mission is continuously developing and evolving.

The aim of this article is to research existing mechanisms for the fulfilment of the third mission by means of a multiple case study taking a university-centric perspective. We investigate the variations and nuances of the university-based third mission models as

they are applied within a specific technology area and as they are perceived and promoted by different core actors across the organisational levels of the universities. This article therefore follows recent calls for future research, e.g. by Fini et al. (2018) and Perkmann et al. (2013), on multi-level studies of commercialisation of public science and the interplay of commercialisation and engagement pathways.

The unit of analysis of this article is the system of mechanisms and the actors involved herein. In doing so, this article identifies five main models of commercialisation and engagement as described in the literature that are salient in the case studies. The empirical study further unveils a sixth model, which is characterised by being highly integrative and collaborative. The article contributes to the literature on the organisation and effects of university-centric models for third mission activities, including organisation of technology transfer offices (TTOs) (Kitagawa, Barrioluengo, & Uyarra, 2016; Sengupta and Ray, 2017; Trencher, Yarime, McCormick, Doll, & Kraines, 2013).

In the following section, the article presents the theoretical background for third mission mechanisms, the actors and facilities involved in fulfilling the third mission, and the aim of the activities. Subsequently, these mechanisms are empirically investigated within a technological domain, namely the research and development of drone technology among Danish universities. Based on the empirical analysis the paper discusses the findings, draws up the implications for university management, and identifies relevant future research themes.

The Third Mission of Universities

The earliest mission of universities was to pursue knowledge for its own sake (M. Klofsten and Jones-Evans, 2000) and to educate students for future employers (Laredo, 2007). A change of perspective was observed from the late 1960s, where the knowledge

produced at universities was not flowing as freely as could be expected, considering its character as a public good. Rather, transfer mechanisms to ensure knowledge flows were required. Simultaneously, the realisation that academic knowledge represented a potential value to capture for the universities led to an emerging focus on a third mission of the universities (Laredo, 2007). In this way, questions of the possible pathways to transfer knowledge, whether for revenue or for collaboration, became part of the university activities.

Since the 1990s, the third mission has been established as a salient concept used for describing activities by universities that are distinct from research and teaching (Secundo, Perez, Martinaitis, & Leitner, 2017), which have an *entrepreneurial* character (Henry Etzkowitz et al., 2019; Magnus Klofsten et al., 2019; Martinelli, Meyer, & von Tunzelmann, 2008), focus on *knowledge exchange* and *transfer* (Cesaroni and Piccaluga, 2016; Rosli and Rossi, 2016), and seek to generate *public value* (Barry Bozeman, Rimes, & Youtie, 2015) and *societal impact* (Fini, et al., 2018; Miller, McAdam, Moffett, Alexander, & Puthusserry, 2016).

These perspectives on the third mission point to a multi-dimensional approach, which does not focus on internal profit generation within the university by means of commercialising academic knowledge, but is based on generating and capturing societal value from public investments in universities (Perkmann, et al., 2013). Hence, the university represents an engine of knowledge creation for public purposes. As the public call for relevant research targeted at societal needs increases, the literature (e.g. Barry Bozeman, Fay, & Slade, 2013; Perkmann, et al., 2013; Rinaldi, Cavicchi, Spigarelli, Lacchè, & Rubens, 2018) assumes that the universities respond by developing new ways for engagement.

The multidimensional nature of third mission activities has led to different categorisations. Foss and Gibson (2015) focus on the commercialisation of research-based knowledge by connecting the third mission to research, which implies that universities act as knowledge hubs for engagement. Alternatively, universities can connect third mission activities to teaching and thereby facilitate the creation of e.g. student entrepreneurial competence. In both cases, the universities use existing academic knowledge to reach out to society through either research or education.

The entrepreneurial university makes technology transfer, firm formation and regional development an academic mission, even as these tasks are integrated into the university's education and research missions (Henry Etzkowitz, 2013, p. 487).

In this way, the third mission becomes a matter of not either or, but of the combination of pathways for engagement that bring the university and relevant outside actors together. Traditionally, the technology transfer office (TTO) has been established as the core engine for commercialising scientific knowledge (M. Klofsten and Jones-Evans, 2000). The original and still often applied model by universities is to seek profit by selling intellectual property rights like patents or licences. Nevertheless, the actual performance of TTOs (setting aside those of the elite universities like Stanford and MIT) are debated (Trune and Goslin, 1998); and some even question whether the activities will ever create revenue (DEA, 2013). Seen from a societal perspective, it is key that the universities address the long-term needs of society rather than focus on short-term profit generation. Altering the mission of the TTO to reflect the multidimensional nature of third mission activities should also be reflected in the performance indicators by moving from internal profit creation to capturing other performance indicators, like an increased number of

collaborative contracts. Accordingly, the assessment of the effectiveness of the third mission activities is widened from the sale of licences or patents to include a long list of new criteria, ranging from whether the technology was transferred ('out the door'), the market impact of the transferred technology, the public value, etc. (Barry Bozeman, et al., 2015).

From Contracts to Engagement

A common denominator for the emerging engagement paths of third mission activities is that they are increasingly becoming *relational* (Nedeva, 2007), as opposed to merely contractual. Secondly, the models have changed from being strictly focused on commercialisation of scientific knowledge to thicken in approach and intensity towards *academic engagement* (Perkmann, et al., 2013). The relational view will often require some degree of reciprocity between the university and the relevant actor (Bjerregaard, 2010; Bruneel, D'Este, & Salter, 2010), whereby the university supplies research-based knowledge, which can potentially lay the foundation for industrially relevant technology development (Mowery and Sampat, 2005). As the third mission changes from an inside-out supply model to an outside-in demand for knowledge, so too do the models of engagement for technology transfer. In this way, the relational view forms a challenge: what are the ways in which the university can bridge academic research environments and industry given the entirely different cultures, approaches and time horizons of the partners involved?

Perkmann, et al. (2013, p. 424) distinguish between commercialisation of academic knowledge through patenting, licensing and academic entrepreneurship, and academic engagement. Academic engagement constitutes knowledge-related collaboration by academic researchers with non-academic organisations in the form of non-formal

technology transfer (op. cit.). Hence, engagement ranges from collaborative research over consulting to networking with practitioners (Perkmann, et al., 2013, p. 424). Perkmann, et al. (2013) further emphasise academic engagement as an extension of the commercialisation of academic knowledge, and thereby make the important point that commercialisation and academic engagement are not entirely distinguishable. The changes in perspectives and activities form new opportunities for technology transfer activities, where academic engagement stimulates the development of new models of technology transfer.

The Actors of Third Mission Activities

It is not only the range of activities that has thickened in recent years, but also the view of the university itself that has changed. Prior literature on the third mission has rested on the assumption that *universities are simple, strategic actors able to respond to a well-articulated set of regional needs* (Benneworth, et al., 2016, p. 732). But universities are far more complex structures; they represent a mosaic of people and units, interests, and domains. Research and administrative units individually have their own logics, partly autonomous and with different intentions and incentive structures for each of the three missions (Benneworth, et al., 2016). For instance, researchers have some degree of autonomy in their work to plan their research, as well as teaching and outreach activities. Hence, achieving the third mission strategies seen from the entity of a university does not capture the complexity of the activities and incentives as they unfold at the different levels and across actor types within the university.

The simple view of the university as one entity has fostered a secluded focus on the TTO as *the* structure for the commercialisation activities handling the scouting process of the university's inventions and research projects, identifying the market and business needs,

and initiating contacts with potential industrial partners (Pinto and Fernández-Esquinas, 2018; Sengupta and Ray, 2017). The TTO has its origins in the early models of technology transfer, e.g. the Stanford model and their technology licensing office (Colyvas, 2007). Since then, a knowledge or technology transfer office for handling the third mission of universities has become the standard organisational response. The mission statements of TTOs emphasise the intent to increase the output of economically relevant knowledge, expertise and patents (Fitzgerald and Cunningham, 2016). Historically, this has led the TTOs to focus strongly on protecting the property rights of the universities through e.g. patents and ways to appropriate returns from property rights for the benefit of the university. However, this has had the downside that interactions between the university and the industry partner have been dominated by contract-based collaboration (the commercialisation of academic knowledge according to Perkmann, et al., 2013). With a thickened focus including innovation, regional development, and mission-oriented activities, the formulated mission statements have developed and the performance metrics for the TTOs have widened. As an example, Fitzgerald and Cunningham (2016) identify target customers and markets as local, national, industry, start-up companies, economy and society, which clearly cover much more than just single industry partnerships for mono-disciplinary discoveries. Pinto and Fernández-Esquinas (2018) studied the effectiveness of the TTO by means of a stakeholder analysis of both research groups and firms in the local regional innovation system. Whereas Pinto and Fernández-Esquinas (2018) point to the importance of researchers' perspectives and interests as stakeholders, they do not explicitly recognise the potential conflicting interests of the researchers and the TTO, despite their shared organisational identity.

Hence, other university actors are also involved in the technology transfer activities. Across scientific disciplines, research facilities or infrastructures are crucial to enabling

research projects to be developed and tested. Whether the infrastructure allows for handling and analysing data (like IT) or comes in the form of laboratories or workshops, it is typically characterised by being financially expensive and requiring regular updates and replacements to enable front-end research to be carried out. Nevertheless, investments in lab facilities are a necessary condition for research and may further support entrepreneurship and research output (Roach, 2017). Price, Matzdorf, Smith, & Agahi (2003) argue that facilities can be essential in attracting key research personnel, can provide environments for faster knowledge creation, and may even attract students to university programmes. The *cooperative technology model* (B. Bozeman, 2000, p. 631; table 1) emphasises that *government laboratories and universities can play a role in developing technology, especially pre-competitive technology, for use in the private sector*. Further, if such facilities are also established by industrial partners, they benefit the local research university as well (Furman and MacGarvie, 2007). In this way, the lab facilities can be interpreted as a meeting place for committing researchers to collaborate with industrial partners. As

...basic science emanating from corporate laboratories has been declining for decades and the rate of commercialisation of basic science in corporate laboratories has remained low (Wright and Phan, 2018, p. 3),

a potentially fruitful path to changing this pattern is to enable and foster industrial partners' access to university laboratories.

Finally, discovery-oriented activities are carried out in research projects by single researchers and hence the research unit and the researcher are the core engines for knowledge creation, and for engaging with industrial partners (Perkmann, et al., 2013). As such, researchers are indispensable actors in the third mission (as well as the first and

the second), but their degree of involvement and their interests and incentives are largely unexplored in research, let alone the individual trade-offs in substituting time for each of the missions.

Whereas research has focused (in considerable depth) on the role of TTOs as engines for third mission activities, this article also points to the role of the research labs and the research groups as core actors and structures in the achievement of the third mission.

From Discovery to Innovation – It's All Part of the Third Mission

Universities and their research laboratories generate scientific discoveries that are marked by high levels of tacit knowledge (Breschi and Lissoni, 2001). Thus, to create value for a broader group of actors (and society as such), these scientific advances must be converted into a form ready for transfer. Either through documentation or as subject for collaboration among actors both within and beyond the boundaries of the university (Powell, Koput, & Smith-Doerr, 1996). This perspective on the ventures of the university is mirrored in the seminal literature on innovation (Schumpeter, 1934) that distinguishes between the invention, which is merely a sound and interesting concept or solution to a problem, and innovation, embodying the successful implementation of the particular solution in a real-life setting.

Where the universities previously focused on commercialising the single scientific discovery through selling patents and licences, the focus today is increasingly on innovation and support of entrepreneurial activities. Specifically, with the vocal attention on mission-orientation to address the SDGs and the Grand Challenges, the focus of commercialisation and technology transfer is thickened from merely finding a path for commercialising a single discovery to new forms of engagement relevant for transferring innovations. The characteristics of Grand Challenges substantiate both the importance of

basic research as they represent fundamental societal problems and the need for big transdisciplinary and interdisciplinary efforts to bring the solutions into use across a broad set of application fields in society (Mertens and Barbian, 2015). These changes also facilitate the third mission activities taking a broader and more complete focus on the entire innovation value chain (Hansen and Birkinshaw, 2007), which in turn leads to the development of new engagement paths.

Five Third Mission Models

The literature has thus far shown that third mission activities include actors at different levels within the ecosystem, new structures and new ambitions. In the following, we condense these considerations to identify a range of models for addressing third mission activities.

The *first* type of transfer model is coined the *Stanford Model*. The Stanford Model emerged in 1968 and has formed the basic model of inspiration for technology transfer activities. Prior to the early 1980s, few US universities were directly involved in technology licensing, and university patenting was modest although increasing. The basic principle in the Stanford Model is that the university should seek to licence as much as possible (Cesaroni and Piccaluga, 2016; DEA, 2013), and this model for licensing is institutionally materialised through an office of technology licensing (Henry Etzkowitz, et al., 2019). The university commodifies the intellectual property rights by maturing the technologies and then capitalising on the basis of licence agreements with commercial actors (Chesbrough, 2003). In this way, the model is based on third mission activities originating in the research mission.

The *second* type is the *Laboratory Model*, which emphasises that access to facilities for industry opens new pathways to creating technology (Lerner, 2010; Miller, et al., 2016).

The companies can gain access to use relevant state-of-the-art research and testing facilities at the university, and through this access meet and engage with researchers to address issues related to their commercial research and innovation projects. In this way, this model is also based on third mission activities originating in the research mission.

The *third* type, the *Knowledge Spillover and Collaboration Model*, is based on the view that the technology itself only represents the tip of the iceberg in terms of the value it generates within the university (Audretsch and Keilbach, 2007). Further, it builds on the fundamental idea that knowledge from the university is a (pure) public good, which is freely available to a range of actors beyond the boundaries of the university (Breschi and Lissoni, 2001). In order to fully realise the potential of the scientific discoveries developed, the university can both engage in a one-way spillover of knowledge to industry (Powell, 1990; Rosli and Rossi, 2016), like contract research; and in a two-way exchange of knowledge encompassing both formal activities (for instance collaborative research and consulting) and more informal activities (such as ad hoc advice and networking, following Perkmann, et al., 2013). Thus, these knowledge exchange interactions also include “softer” mechanisms, such as consulting, contract research and (external) teaching activities (M. Klofsten and Jones-Evans, 2000). In this way, the third model is also based on third mission activities originating in the research mission.

The *fourth* type is the *Spin-out Model*, which is based on the idea that the TTO has a key role to play when the university capitalises on the inventions that are developed within the university. The TTO scouts the various activities within the university to do an early-stage assessment of the inventions with the most promising potential to form the basis of a start-up spinning out of the university. Thus, the Spin-out Model represents a shift from the first three types of third mission models, because it focuses on the university as a potential market actor (Lockett and Wright, 2005) that seeks to bring the scientific

discovery through commercialisation to actual innovation (Xu, Wu, Minshall, & Zhou, 2018). In this way, this model draws on the research mission, but may link to the educational mission if student entrepreneurship is institutionalised through the TTO.

The *fifth* type is the *Incubator Model*, where the university builds facilities and infrastructure, which support interaction among researchers, companies, and students. The Incubator Model holds three components: (1) Business support to new ventures within the incubator; (2) mediation between the industry and university actors; and (3) selection of the most promising ventures within the incubator (Bergek and Norrman, 2008). These activities may result in ideas spinning out in new companies (Di Gregorio and Shane, 2003), reflecting an overlap with the previous model; in ideas that mature into new products; or in simply building competencies in entrepreneurial ventures. However, the level of technology transfer is not the specific technology (as with the Stanford Model) but is the potential innovation, which when mature enough, forms the basis of a start-up company. In this way, this model draws on research originating in the research mission and connects this with the educational mission. The target is not the spin-out itself but the process of developing business cases, learning to mature technologies, and to identify market opportunities through partnering.

Research Approach and Case Selection

Our empirical research focuses on whether and how Danish universities apply the different models by means of two case studies that, vis-à-vis large-sample empirical work, make it possible to get closer to theoretical constructs (Piekkari, Welch, & Paavilainen, 2009). Thus, methodologically, the article is based on theoretical sampling (Eisenhardt and Graebner, 2007), where the analysis of the cases is expected to fertilise and substantiate our understanding of the five models.

Focus and Performance of Danish Universities

From the 1980s onwards, the Danish science policy has increasingly focused on the need for universities to patent their inventions (Sejersen and Hansen, 2018). In 1995, the national research strategy included a key ambition of facilitating commercialisation of Danish research and, in 1999, an Act on Inventions was introduced to increase knowledge transfer from the universities to industry (ibid.). An updated national research strategy was published in 2017 (Regeringen (the Danish Government), 2017, p. 23) in which the Danish Government formulates two overarching ambitions: Danish research 1) must be of the highest possible international quality – up to Nobel Prize level – and 2) must be of maximum benefit to society. As part of the second ambition, *the public effort in relation to knowledge-based innovation must efficiently support industry's needs and innovation activities and thereby create increased value in the Danish companies – especially in small to medium-sized companies*. In this way, the strategy follows the view of Foss and Gibson (2015) in regarding impact as departing in the research mission. A second strategy was presented in 2016 for promoting drone development and use in Denmark (Regeringen (the Danish Government), 2016). This strategy encourages Danish companies to collaborate with researchers on the development of drone technology for the purpose of creating jobs. Thus, the political focus on universities' collaboration on innovation with actors outside academia stands out distinctly.

A study from the Danish think tank, DEA (2016), confirms that the Danish universities are increasingly expected to contribute more directly to economic growth, primarily through collaboration with industry and by actively furthering commercialisation of the research conducted at the universities. Like many other countries, Denmark has implemented a research patent legislation (2000) to make the Danish universities responsible for commercially exploiting new discoveries arising from research conducted

at the universities through sales of intellectual property, i.e. patents (DEA, 2013). An evaluation of the universities' performance has led to the conclusion that this type of technology transfer is unlikely to ever create revenue for the universities (ibid.), which is nevertheless also not a requirement (Styrelsen for Forskning og Innovation (Danish Agency for Science and Technology), 2019). The creation of spin-out companies is also not a fruitful avenue towards profit, since most spin-outs from universities remain small and grow less than other high-technology companies (DEA, 2016).

The universities' technology transfer is therefore not under political pressure to be a revenue source, but may be viewed as an investment in disseminating knowledge to industry (DEA, 2016) and intellectual property as a lever to facilitate collaboration with companies (Universities Denmark, 2011). National analyses have confirmed that companies significantly enhance their productivity and revenue by collaborating with Danish universities on R&D projects (Universities Denmark, 2016).

The Danish universities have defined and formulated strategies for their collaboration with industry, and they have increased their collaboration with companies (DEA, 2016). The increase is seen both in terms of number of collaborations and types of channels for collaborating (e.g. through interdisciplinary research projects and long-term technology development projects) (DEA, 2016).

In addition to the above focus areas, Danish politicians expect that the Danish universities contribute significantly to growing regional/local innovation systems (DEA, 2016), and some universities, especially those in regions with only one university (Inside Consulting and Copenhagen Economics, 2006), do increasingly and closely collaborate with the actors who are responsible for regional development.

Multi-Level Case Studies

To investigate the universities' third mission strategies, we focus on a specific, high-technology research area rather than making a broad analysis of all activities. In this way, we can trace the models that are used in more detail. The research analyses how two Danish universities, namely the University of Southern Denmark (SDU) and Aalborg University (AAU), seek to fulfil the third mission within the research area of drones.

Key indicators	Year	Aalborg University (AAU)	University of Southern Denmark (SDU)
Number of researchers	2016	1,890	1,975
	2017	1,954	1,944
	2018	2,020	1,936
Number of employees (total)	2016	3,351	3,772
	2017	3,431	3,766
	2018	3,498	3,815
Share of researchers to employees	2016	56.4	52.4
	2017	56.9	51.6
	2018	57.7	50.7
Number of employees working in technology transfer-related activities	2016	n.a.	n.a.
	2017	53	80
	2018	n.a.	n.a.
Number of inventions (reported)	2016	68	35
	2017	71	36
	2018	81	43
	Total	220	114
Number of patent applications	2016	14	6
	2017	16	14
	2018	11	13
Number of spin-outs	2016	1	3
	2017	1	3
	2018	2	4
Number of partnerships with industrial partners	2016	1,210	934
	2017	1,225	946
	2018	1,255	888
	Total	3,690	2,768

Table 1: Key figures for the two case universities.

Table 1 illustrates the similarities of the two case universities on a range of key figures. Both universities are deeply involved in drone technology research and development and are regarded as core research actors in the field. They were remarkably active contributors (compared to other universities with drone technology research) to the recent Danish drone strategy (The Danish Government, 2016).

	SDU UAS Center*	AAU Drone Research Lab**
Year of establishment	2015	2015
Organisation	A unit within the Faculty of Engineering	A unit within the Faculty of Engineering and Science
Number of employees (full-time equivalent)	23 (2019)	11 (2015)
Main drone technology research foci	Control systems, embodiment, embedded electronics, model-driven software development, perception and computer vision systems, and robotics integration	Autonomy, communication, safety and risk, industrial use, human-drone interaction, programming and verification
Drone education	MSc in Engineering in Drone Technology as a specialisation within the MSc in Robot Systems programme	Takes place within different educational programmes at the university, where students can choose drones as a theme
Indoor research and education facilities	Composite lab, motion capture lab, system integration lab, access to industry 4.0 lab, and more	Motion tracking lab, audio visual arena lab, antenna lab, materials and manufacturing lab, robotics vision, and machine intelligence lab
Outdoor research and education facilities	Test field in local commercial airport, including 867 km ² drone airspace for test flights	Local hobby airfield is used as flight test facility

Table 2: Drone research foci and activities at the two universities.

*https://www.sdu.dk/en/om_sdu/institutter_centre/sduuascenter; **<https://www.drones.aau.dk/>

Table 2 lists the drone research foci and activities at the two universities and highlights that their activities within this research area can serve as a field of comparison, as they are based on most similar systems design. In addition, both universities are characterised by being the only university in their region (southern and northern parts of Denmark, respectively). In a recent investigation of the collaboration between the eight universities

in Denmark and 300 Danish companies (Hoff, Pyndt, & Rønhof, 2018), SDU and AAU received the most positive ratings from companies of all the Danish universities: 84% (SDU) and 87% (AAU) of the companies found that their collaboration with the two universities had been “very good” or “good”. The investigation showed an increased satisfaction compared to 2014, where the ratings were 60% (SDU) and 72% (AAU). Hence, the two universities have improved the scores for their relationships with industry within the period of four years. Furthermore, both universities have, according to their strategies, a strong focus on third mission activities. For instance, SDU writes in its strategy¹:

Many challenges in our society now feature such complexity that it's simply impossible for any single institution or company to deal with them using only their own resources.

In this way, the collaborative focus is strong and inherent in the strategic focus of the university. For the theoretical underpinning, we have therefore selected cases that have a strategic focus on the third mission and are comparable within the technology area. SDU's and AAU's models for fulfilling the third mission are investigated from three different internal perspectives, namely according to (1) top management; (2) the heads of the innovation offices and/or TTOs; and (3) the research directors of the research units. Hence, the data collection encompasses both the universities' overall vision and mission in relation to fulfilling the third mission, the specifics on how the universities prioritise and organise third mission activities, and third mission activities particularly in relation to the universities' drone technology research.

¹ https://www.sdu.dk/en/om_sdu/strategi/vaerdi_for_og_med_samfundet (access: June 2018).

Choice of Technology: Drone Technology Research and Collaboration

Drones are expected in the future to become an important part of our daily infrastructure (EU, 2014). As an example, drones can be used for performing a range of so-called dull, dirty and dangerous tasks and have the potential to replace existing jobs. However, they can also enable missions that previously could not be carried out, such as providing medicine to distant and impassable destinations.

Although drones have now become *inexpensive and extraordinarily capable flying robots* (Jacobstein, 2013, p. 15), a drone is in itself just a technology platform. When equipped with e.g. GPS, a video camera, a processor, Wi-Fi, etc., it can give us extended access and yet unknown information (Lygum et al., 2014). Drones are often associated with military missions, but the rapid technological development of sensors, batteries, fuel cells and lightweight materials, etc., make drones for civil and commercial purposes ever more interesting and appropriate (ibid.). The drone technology is expected to create 150,000 drone-related jobs (excluding employment generated through drone operator services) in Europe by 2050 (EU, 2014). Despite the many potential applications and rapid technological acceleration, the field is still characterised by an ill-defined market and yet-to-be-explored technology (Jacobstein, 2013).

In Denmark, drones are also expected to become an important tool for a wide variety of mission types, e.g. search and rescue operations, inspection of infrastructure, collection of visual data, etc., which has led the development of drone technology to receive tremendous attention in Denmark, both from researchers, companies, authorities, and politicians.

The Danish drone industry is generally in a pre-paradigmatic stage (Abernathy and Utterback, 1978) characterised by technical and target uncertainty, and it consists mainly

of small companies with limited financial and human resources. Even though there is a strong need for research and development, most of the investments for this come from public and private foundations and accrue mainly to the universities. This set-up makes drone technology research in Denmark a relevant case for studying universities' third mission activities and emerging engagement paths. SDU and AAU are particularly relevant universities for this study, because they account for the bulk of research in Denmark on drone technology for civil and commercial use.

Data Collection

Univer- sity	Interviewee and role in relation to drones	Type of interview	Duration of interview (minutes)
SDU	Dean at the Faculty of Engineering: Involved in ensuring (also drone) technology research at the university.	Face-to-face	91
	Head of SDU Research and Innovation Organisation (SDU RIO): Responsible for the university's interactions with industry and society at large.	Face-to-face	127
	Head of TEK Innovation: Responsible for building bridges between the Faculty of Engineering and the surrounding society.	Skype for Business	35
	Leader of SDU UAS (drone) Center: Focuses on research and development of drone platforms and associated technology.	Face-to-face	111
AAU	Vice-Chancellor: Involved in ensuring (also drone technology) research at the university. Former Dean at SDU, where he was involved in establishing drone technology research.	Face-to-face	62
	Innovation Director: Responsible for the university's interactions with industry and society at large.	Phone	42
	Head of Technology Transfer Office: Involved in seeking market opportunities for technology developed by researchers.	Face-to-face	68
	Director of AAU Drone Research Lab: Focuses on research and development of drone platforms and associated technology.	Skype for Business	55

Table 3: Overview of the interviewees.

To gain deep insights from relevant actors (Yin, 1994) into how the two universities consider and develop engagement models to fulfil the third mission, semi-structured interviews were carried out. The interviewees (Table 3) were selected, because they are considered key persons in relation to the topic, and they cover the different levels at the university: top management, the innovation offices and/or TTOs, and the drone technology research units. The interviews were conducted from May 2016 to May 2019 by means of interview guidelines outlining the main issues to be covered but enabling the interviewers to decide on the sequence and phrasing during the interviews. The interviews lasted 73 minutes on average, were sound recorded, and subsequently transcribed.

Secondary Data

Secondary data were included by studying (1) the websites of SDU and AAU, which revealed that both universities had re-organised the existing TTOs to strengthen the existing model for collaboration and engagement. Coincidentally, both universities happened to advertise for new heads of innovation offices, and we included the job adverts to understand the visions and ambitions. Finally, we included the annual reports of the universities (2018), PowerPoints and the like from the universities' innovation offices, evaluation reports outlining the prioritising, organising and outcome of third mission activities at the Danish universities, including SDU and AAU, and national documents relating to research in drones, like Denmark's Drone Strategy (Regeringen (the Danish Government), 2016). This process of data collection went on until Q2 2019 to include the most recent developments.

Data Coding and Analysis

The interviews, the workshop dialogues, the job adverts, the PowerPoints, the evaluation reports, and the drone strategy were coded by one of the authors using NVivo 11. A

deductive coding approach was applied that focused on the five models identified in the literature (the Stanford Model; the Laboratory Model; the Knowledge Spillover and Collaboration Model; the Spin-out Model; and the Incubator Model). The coder also included statements that were of relevance to understanding emerging engagement paths of the universities, or that described the vision and mission of the two universities. These statements were coded inductively. The two other authors checked the coding by reading through the statements related to each model, and – although the data analysis was made by the coder primarily – all three authors discussed the statements, how these related to the aim of this article, and how they were to be interpreted. When reporting the findings, the interviewee statements were translated from Danish to English – except those stated by the Leader of SDU UAS Center, since this interview was conducted in English.

Findings: Management Visions for the Third Mission

Vision and Mission of the Two Universities

SDU and AAU do well according to the latest report on collaboration with companies (Hoff, et al., 2018), and the two universities prioritise such efforts. Both universities reorganised their technology transfer activities in 2016/2017, including their TTOs. SDU created a new unit, SDU RIO (Research and Innovation Organisation), which among other tasks includes a focus on technology transfer activities. The job advert for a new head of SDU RIO emphasised SDU's overall vision and mission as well as the purpose of establishing the unit²:

SDU's objective is to create value for society through research and research-based education as well as knowledge exchange. In relation to the core output, it

² Application deadline: 24 October 2016.

is crucial to collaborate in a relevant and innovative way with the surrounding society. This requires a massive effort aiming at strengthening SDU's societal commitment. (...) SDU already has a number of constructive and productive initiatives and wants to build further on this solid platform; the initiatives are gathered in a newly established unit that will work towards advancing value creation and commercial activities.

Around the same time, AAU advertised for an innovation director for an upcoming innovation and research support centre (AAU Innovation)³ including their technology transfer activities:

AAU strengthens its position as a leading university within innovation and collaboration with public and private organizations. The university will leave its mark on the innovation political agenda and contribute to value creation in society. AAU believes that collaboration creates new and improved knowledge for the benefit of both universities and the world. Researchers and students will actively disseminate the newest knowledge and act as knowledge resources that will be the mainspring of development.

Both universities emphasised in their job adverts the need for strengthening their impact-oriented activities with industry and society, and the immediate means was by re-organising existing units to intensify the focus on innovation. Both universities in the end hired experienced managers as new heads of units.

³ Application deadline: 8 September 2016.

Purpose of the Re-organised Units

The re-organised units differ in size: In 2017, SDU RIO had 80 employees and AAU Innovation had 53 employees (in 2017, SDU had in total around 3,750 full-time equivalents and AAU had around 3,450 full-time equivalents). As part of the re-organising process, both universities unified several existing units into one organisation. The Head of SDU RIO and the Vice-Chancellor as well as the Innovation Director of AAU (Head of AAU Innovation) emphasise the expediency of a unifying effort. Gathering all employees within incubation, contracting, and commercialisation around one unified goal and in one unit was intended to ease the design of teams to be able to provide a full service to the universities' research environments and to external collaborators.

The Dean at SDU further emphasises that, with the re-organisation, the university introduced a change of responsibility:

... the academic leadership is responsible for ensuring the delivery of impact and quality (as value created from business-oriented activities), i.e. the Vice-Chancellor, the deans, the heads of department, and the heads of research. SDU RIO is there to meet the needs for help and support as requested by the academic environments.

The intention with the attention of the academic leadership is to ensure that SDU's research groups become more clearly involved in and are also made responsible for entrepreneurship and innovation and not just research. Hence, the academic environments now have three different bottom lines to focus on (research, education and outreach) and are accordingly expected to instigate e.g. collaboration with industry. SDU RIO will then

support the researchers, when they ask for it, by providing access to and building networks, handling legal aspects, etc.

AAU uses a different model. The Vice-Chancellor states that:

I want an innovation unit with a one-stop shop. (...) ... we must not ask the researchers (...) to be the ones, who are responsible for the collaboration with the companies. This is the job of the unit (AAU Innovation).

Hence, at AAU, the collaboration with the surrounding society is first and foremost the responsibility of AAU Innovation.

Importantly, both universities find it expedient to have dedicated, physical locations for furthering innovation and entrepreneurship. In October 2015, SDU opened its Cortex Lab, which is a 3,000 m² innovation and entrepreneurship environment with workshop areas, offices, and prototype facilities for students, companies and researchers to experiment together and create businesses. AAU is currently developing its coming Science and Innovation Hub, which is expected to open by the turn of the year 2021/2022. It will be an 8,500 m², seven to eight-story building intended for cross-disciplinary research, innovation, entrepreneurship, talent development and business development. In this way, both universities stress the importance of physical locations as meeting places for interaction, but have applied different models for third mission activities.

Findings: Third Mission Models in Drone Technology Research

The analysis accounts for differences in perspectives within and between the two universities when the differences are salient in the data.

Findings Relating to the Stanford Model

The findings show that models and attitudes towards patenting and licensing of scientific discoveries differ somewhat between SDU and AAU.

The Leader of SDU UAS Center would like to see patenting and licensing as a feasible pathway for his employees, so that they can get the most value out of their work. He therefore encourages them to keep track of who does what in connection with research and development projects:

... what I have told everyone is to document, document, document. So, you know, keep logs, something that has a time/data stamp, and be able to document that, you know, this is your intellectual property, it was created by you, it wasn't somebody else's, and it was done on this date, etc.

However, at the same time he shows awareness that other priorities must also be accounted for. As the centre was only established in the mid 2010s and most companies in the Danish drone industry are smaller entrepreneurial companies, other mechanisms are likely to be more relevant:

I think that at least for the first couple of years, we are going to give up some things simply to strengthen our foundation as a good partner and to send a signal to others that 'hey, you want to come and work with us'.

The Head of TEK Innovation at SDU states that

... the mission (of the university) is to create value based on the research that we produce. (...) Sometimes, we develop new technology, and that is the main part of the third mission; to get it (the technology) closer to the companies. And then have a set-up (at the university) that supports the smoothest way from invention to patent or creation of a start-up or... We operate with many models.

The Dean at SDU advocates that the full range of methods of maturing an idea and bringing it to the market, ranging from early technology sale to in-house incubation with proof of concept and proof of business, should be used by the university. What is optimal depends in part on the market and on the complexity of the product or service. Although SDU sees potential in patenting and licensing, the Dean warns against being driven predominantly by the desire to generate a lot of profit:

... we must be careful not to think that, because we have patented it, it will lead to highly profitable situations at the university – that is not the reason why we are here. (...) ... we shouldn't be thinking 'SDU first'; we should think of society and the industry in general. (...) Therefore, when we apply for patents, it must not primarily be motivated by what is best for SDU; we must think about how an idea can be commercialised successfully (by a company).

According to the Head of SDU RIO, there is generally a need for universities to consider how they can aid innovation rather than sticking to selling inventions based on the Stanford Model. This could be done by giving inventions coming from university researchers to companies and then rely on the companies' goodwill, i.e. that they will give something back to the university. No matter the approach, the Dean at SDU is aware of the need for ensuring that the researchers are motivated when handing over their inventions to a company:

... it is very important that the spark of the inventors (researchers) is maintained, so that they are not merely 'salary slaves' doing what they are told.

According to AAU's Head of Technology Transfer Office, patents are not a salient part of the university's agenda:

We are more willing to take risks than many others. We are the ones protecting the least by far considering that we are by far the ones selling and commercialising the most.

This view is supported by the Vice-Chancellor at AAU:

We simply don't believe in patents. ... (..) the ministry measures us on patents. We, however, measure ourselves on job creation. (...) We think that the companies should apply for the patents; that's the reason why they are here. And then they should make business based on it. (...) In this way, we save ourselves from intolerable discussions about intellectual property rights.

Despite these strategic perspectives, the national accounts show a significant increase in patent applications for AAU (see Table 1).

However, just like the Dean at SDU, the Vice-Chancellor at AAU sees potential in a more indirect way of gaining profit from inventions through the embodying of different clauses, such as royalties, in the contracts that the university enters into with companies. The number of contracts has, however, been decreasing for AAU (c.f. Table 1 – from 934 to 888; approx. 5% decrease), whereas it has been increasing for SDU. The Innovation Director at AAU emphasises that, even though co-creation is high on the strategic agenda of AAU, the traditional, sequential model (the Stanford Model) remains relevant to fulfilling the third mission. She explains that, as part of her focus on systematising innovation efforts at the university, she focuses on the overall innovation ambition of the university to also identify new discoveries:

Our approach to innovation is that new discoveries must be useful (...) and we wish to take it a step further in seeing to it that they are also made use of. That we as a

university take responsibility, also for the last part of the journey, instead of merely leaving it up to others to find out whether and how a new discovery is useful.

Both SDU and AAU wish to maintain strategic partnerships with companies in relation to technology development. For example, the Head of SDU RIO mentions the desire to enter into more strategic, deeper, and long-term collaborations between the university's research environments and companies. AAU also expresses a focus on business alliances but, as emphasised by the Vice-Chancellor, the university has been too eager to work with the surrounding society and has said 'yes' to almost anything. He therefore asks his employees to ensure value from such collaborations:

Per definition, I'm against collaboration agreements where we do it for free. And during the last two years, the number of collaboration agreements has dropped, whilst the turnover per agreement has increased significantly. Thus, my message is sort of understood.

Findings Relating to the Laboratory Model

SDU offers access to its equipment on a commercial basis for companies. For instance, companies in need of handling very large amounts of data can buy access to the computing power of Abacus 2.0, a super computer⁴. For the drones, companies can get access to SDU's drone laboratories located in the Hans Christian Andersen Airport near the university. At the labs, companies can test their (drone-related) technologies, both indoors by using the laboratory facilities and outdoors, where e.g. the flying capabilities of a drone can be tested in the surrounding airfield and airspace.

⁴ Access to Abacus 2.0:

https://www.sdu.dk/da/om_sdu/fakulteterne/naturvidenskab/arkiv/nyheder_2015/2015_12_02_more_abacus. Abacus 2.0 is guided by a partnership between DeIC, SDU, AAU and Aarhus University.

The Vice-Chancellor at AAU mentions that the university has equipment in their workshop and laboratory facilities that companies might want to pay for access to:

... we could have some technicians making a living from providing services in relation to e.g. metrological tasks. (...) ... most of our equipment is not being used for longer periods of time. Why don't we use it to provide a technological service? (...) The research groups may even be able to generate an income based on this, if they have a technician who does it.

The Innovation Director of AAU also emphasises the opportunity for companies to gain access to the university's laboratories and financing it either through public funds or by letting the companies pay for using the facilities whenever these are not in use. The universities therefore see potential for revenue generation in providing access to the facilities, but they do not mention the possibility for co-using the equipment or possible collaboration opportunities by connecting researchers and partners around the equipment. AAU even mentions that it should be in the "unused periods".

Findings Relating to the Knowledge Spillover and Collaboration Model

Both SDU and AAU stimulate collaboration between the companies and their researchers on research and development projects. The Dean at SDU formulates the benefits:

There must be a lively traffic between the companies and the public knowledge environments (the universities) in such a way that their (the companies) challenges inspire our research and our research inspires their ambitions.

The Head of TEK Innovation at SDU experiences that his unit sometimes must act as a bridge-builder between companies and researchers:

The relationships are there (anchored in the research units). However, the relationship is not always really there. Therefore, we can help to create it.

The Dean at SDU emphasises that, as a university:

... we can take on the research and development tasks that are too risky for the companies (...) ... well, like in any other type of R&D activities, there must be a reasonable division of labour.

Therefore, collaboration agreements must be entered into, although it can be a time-consuming task, as explained by the Leader of SDU UAS Center:

It took us two months to put together the collaboration agreement for the FreeD ('Free the Drones') project. (...) This is where, you know, intellectual property is created, and then there can be the fight over whose was it, you know, how much is it worth, who has rights to it, etc.

The Head of TEK Innovation at SDU mentions other ways of ensuring knowledge spillover to companies than by means of project collaboration. It could be by offering consultancy:

We as a university can offer our knowledge on commercial terms, as long as these mirror the market conditions. (...) In case we possess unique knowledge within a field that could be brought into play (...) e.g. for technology development.

AAU's Head of Technology Transfer Office believes that the researchers at the university naturally and actively look for ways of collaborating with companies; especially because the researchers need to obtain external funding for their projects. The Director of AAU Drone Research Lab confirms the collaboration focus:

... we collaborate to a large extent, i.e. almost all the projects (also research projects) we are running involve collaboration with companies. Thus, I have a lot of contact with the industry.

The Innovation Director of AAU believes that collaborating with the surrounding society is encoded in the university's DNA. She supports this by referring to a qualitative investigation by an external consultant on how the employees at the university perceive this demand. The conclusion is that most of the employees are in favour of collaborating with external actors and that bringing an enterprise to the assignment actually is how the research units work. The Innovation Director suggests that researchers should collaborate with the entire value chain of companies and become present in e.g. industry clusters with the purpose of networking and growing project funding opportunities. Considering the time pressure on researchers, the Vice-Chancellor at AAU stresses the importance of ensuring that the researchers spend their time wisely:

They (the researchers) are not supposed to be project managers; they should not waste their time on this more than necessary. They must use their expertise (in the given project) and then return to their research.

The Innovation Director of AAU emphasises a mismatch between ambitions and both regulatory and financial conditions for researchers to engage in collaborations with e.g. companies. According to her, the universities should generally have more freedom to decide how to accomplish the third mission. Moreover, she sees a challenge in education and research activities as being both measured, but also part of the qualifications needed for promotion, whereas outreach and innovation activities, i.e. activities directed towards fulfilling the third mission, are generally not.

Overall, the universities emphasise the need for carefully considering how collaboration is done at the individual and group level; both with regards to intellectual property rights, work load, and incentives.

Findings Relating to the Spin-out Model

The Dean at SDU ponders what it takes for a researcher in the middle of his academic career to pursue a good idea and become the CEO of a start-up with highly uncertain prospects. The Dean encourages researchers to grapple with entrepreneurship, and he generally provides a safety net for permanent staff to pursue opportunities. He gives an example of a recent spin-out from the university:

I have promised our researcher a leave of absence, meaning that he spends 100% of his time in the company but can come back if everything 'crashes'. This is to ensure that he dares to go for it.

The researcher was even offered the opportunity to teach on a part-time basis for a few years so that he had an income in the start-up period. The Dean continues by emphasising that the university values researchers taking risks:

If you have been out there and successfully or unsuccessfully formed a start-up, you will have gained valuable experience, and we (the university) are happy to welcome you back – and consider that this experience has increased your qualifications relevant to the university.

AAU's Head of Technology Transfer Office mentions that in the university's strategy there is now much more focus on entrepreneurial researchers. He adds that his office has assisted in quite a few spin-out creations. Thus, both SDU and AAU focus on potential spin-outs of the universities, but none of the universities have a substantial track record yet.

Findings Relating to the Incubator Model

The Incubator Model is prevalent at both universities. Overall, the Vice-Chancellor at AAU emphasises research as a great opportunity – through incubation at the university –

for creating a business venture. However, AAU's Head of Technology Transfer Office questions the motivation of researchers to pursue such a career:

I've seldom met a researcher who wishes to say goodbye to his research career and step into a completely underfunded company driven by a public innovation manager. I simply don't believe that anyone thinks of this as an inspiring way of terminating the effort one has made to create a (research) career.

In support, the Dean at SDU states that:

... if it is uncertain whether a business can actually be created based on this (the invention), well, then SDU might come onboard and help commercialise it for a period of time. (...) However, a model could very well be that we would like the inventors to own a significant part of it, which will only be motivating.

The Leader of SDU UAS Center supports this, while emphasising a different model for commercialisation activities:

*... how I would go about it is to marry them (the researchers) up with a company (...)
... most of the things that everyone is working on are like TRL7 (technology readiness level 7; prototype built solving small but user-relevant problems), and then they don't have the funds or the company structure to take it into production and, you know, into the market.*

He goes a step further by suggesting also investing in companies that are not spin-outs of the university:

*I have told them (a drone technology provider) that, if I had some money to invest, I would invest in them, because I think that they have the potential to take off, and (...)
I see them right at the bottom of this exponential curve. (...) I think we should be looking for those opportunities (...) ... can we tap into the company?*

Hence, having a good sense of the market and investing in companies outside the university setting could be a new path to follow in support of the Danish drone industry, but also to stimulate further third mission activities. Notice that the Leader of the SDU UAS Center points to a relational perspective on spin-outs as contrasted to the top management, who favoured a model where the researchers themselves pursue the spin-out with resulting incentive considerations.

Both universities also support students with a desire to create start-ups. The Innovation Director of AAU explains that AAU Innovation is currently systematising the pathway for students at all faculties to become entrepreneurs:

We actually assume co-responsibility for seeing to it that our students start their own companies; based on the knowledge they acquire at the university, that is.

She finds political goodwill and focus from the Danish Minister of Science, Technology, Information and Higher Education, who tirelessly emphasises that it is more important than ever that students create start-ups.

So, for the Incubator Model, the universities are interested and see potential, but currently the success is limited (see Table 1). This may relate to the comment from AAU's Head of Technology Transfer Office, who questioned the overall motivation of researchers to make the needed career change.

Additional Findings: A New Engagement Model

The findings confirm that the five third mission models identified in the literature are used – to varying degrees – within drone technology at the two universities. However, an additional type emerged from the inductive coding of the data. This emerging third mission model can be labelled the 'Ecosystem Model', as it refers to the involvement of

a range of both public and private actors collaborating on furthering the development of the drone industry.

Findings Relating to the Ecosystem Model

The advanced nature of the drone-related technology, the modularity of technologies for integrated solutions, the emerging nature of the drone industry as characterised by the immature demand for drone solutions, and hence the small size of the technology providers, are all aspects underlining that development of innovative solutions requires some collaboration with the universities. Some of the interviewees stress the important role of the universities, e.g. the Dean at SDU:

... we, the universities, have a central role to play in developing (drone) technology that enables it (the development of the drone industry). (...) ... we must help develop the underlying systems, such as in 'Free the Drones', which is precisely revolving around the development of key enabling technologies that are needed for e.g. Amazon to start delivering their parcels more widely.

He envisions that there will be a Danish drone cluster established similar to the one within ground-based robotics⁵ and that the drone technology providers will be located mainly in Odense (close to SDU). However, he is aware that this development takes time and therefore encourages a long-term view of the university's performance:

... one must be aware that 10 years for building something like this is actually pretty fast, and we need to be patient, which includes perseverance...

⁵ <https://www.odenserobotics.dk/>

Hence, both support and patience are needed to facilitate the development of the Danish drone industry. The Head of SDU RIO emphasises the need for an interdisciplinary model:

... when a problem needs to be solved (...), it is not only the engineers that you need; you need all sorts of disciplines. (...) In relation to drones, you have all these ethical issues (...) ... it is crucial that we get legal experts involved. (...) We are leaning much more towards interdisciplinary collaboration to enable innovation and making a difference.

He further emphasises that SDU RIO must focus more distinctly on supporting efforts towards the emerging Ecosystem Model:

... what kind of support does SDU RIO need to provide to the research environments that wish to engage in more long-term, strategic and deeper collaborations with e.g. a cluster or an industry? It would be great if we (SDU RIO) could develop this.

As mentioned earlier, the Director of AAU Drone Research Lab collaborates extensively with companies, since all the lab's research projects are made in collaboration with industry partners. He emphasises the importance of projects involving various actors from the drone innovation ecosystem:

... firstly, I think this is a good way of doing it. And it gives us, the universities, a huge responsibility for developing something that enables it (the development of the drone industry). Thus, I think this is a prudent way of dividing things, and it can really provide progress.

Both universities thereby recognise their role in supporting the development of the drone industry. At AAU, only the Director of AAU Drone Research Lab explicitly addresses this aspect, and thus the Ecosystem Model is not articulated at top management or TTO

level at AAU. SDU on the other hand is already seeking to advance the Danish drone innovation ecosystem, especially through participating in and running two externally funded projects: 'Free the Drones', where the university – in close collaboration with e.g. the Danish transportation authority and drone technology providers – focuses on developing fail-safe technology with the aim of expanding the use of civil and commercial drones; and 'Innovation on Wings', where SDU together with UAS Denmark, the Danish drone industry cluster organisation, plays an active role in helping and advising drone technology providers on how to develop their businesses towards a maturing industry. This is done by e.g. conducting 1:1 sparring workshops and organising match-making activities, where potential customer firms meet and collaborate with a range of drone technology providers. Both projects were established by research units at SDU, i.e. the initiatives came from this level of the organisation based on an understanding of the need to help accelerate the drone industry, as explained by the Leader of SDU UAS Center:

There is recognition by everyone that this is a growing industry (the drone industry) and that there is lots of capital or money to be made from a market perspective. But the only way that everyone will get there is if we all push for the same direction in terms of the regulations, the technology, the projects that we are working on, and the direction that we are going. With the limited resources that we have here in Denmark (...) the expertise of each one at the universities is going to contribute to the ecosystem.

Overall, SDU is aware and supportive in focusing on promoting the ecosystem and cluster development with an explicit innovation and business development perspective. According to the Head of SDU RIO, it is important that the university takes on such a role because of a lack of large companies in an emerging market that can define and pull

technologies in the direction of innovative solutions. Moreover, he emphasises that the university needs to and has the potential to ensure a focus on regional industry development. These perspectives are clearly outside-in and coming from an innovation and market development perspective and originating from the research group level.

Outlining of the Findings Relating to the Third Mission Models

As illustrated in Table 4, the third mission models applied by both SDU and AAU draw from several categories. It is therefore important to stress that the universities do not follow one model, but blend aspects of the different models into their own unique combination of engagement paths. These depend on the strategic perspectives from top management, initiatives from the research groups, entrepreneurial interests of the researchers, and the role of the TTO and/or innovation office.

The various models encompass: transferring inventions from the university to industry (the Stanford Model and the Spin-out Model); providing access to the universities' facilities and expertise (the Laboratory Model and the Incubator Model); collaborating on research and development projects with companies (the Knowledge Spillover and Collaboration Model); and seeking to advance industry and (regional) cluster development (the Ecosystem Model).

The general tendency is for the two universities to emphasise collaboration, entrepreneurship and innovation much more than simply patenting scientific discoveries, which supports the engagement perspective over the simple commercialisation perspective. Neither SDU nor AAU perceive patents and protection of intellectual property rights in general as a core task. Instead, it is emphasised that patents should flow smoothly (although not entirely for free) towards companies. From the outset, both

universities have by and large focused on the Stanford Model and from that pursued slightly different development paths in their third mission models.

...aspects of...	University of Southern Denmark (SDU)	Aalborg University (AAU)
The Stanford Model	Early technology (patent draft) sale	
	Patenting and licensing of technology	Patenting and licensing of technology, but the university focuses less on this and more on leaving ownership of inventions to companies; however, not for free, as the university gets e.g. royalties
	Strategic partnerships in relation to technology development	
The Laboratory Model	Companies can pay for access to equipment and facilities, e.g. workshops and test laboratories (companies can buy time, expertise in using the equipment, or even man-hours for the actual development of new products)	Considers giving companies access to equipment and facilities
The Knowledge Spillover and Collaboration Model	Researchers offer consultancy	
	Researchers collaborate with companies on research projects	
	University-industry collaborations with a reasonable division of labor, e.g. through collaboration agreements	
The Spin-out Model	Researchers, who create their own company, are welcome to come back to the university at a later point in time	
The Incubator Model	The university supports or even co-invests in start-ups and spin-outs (students or researchers, who start a company and use the university as an incubation setting)	The university supports start-ups and spin-outs (students or researchers, who start a company and use the university as an incubation setting)
The Ecosystem Model → while drawing on the third mission models already taking place	Researchers act as advisors to e.g. technology providers and policy makers to help advance the innovation ecosystem of an industry	
	(Interdisciplinary) research units help accelerate the development of ecosystem and companies	

Table 4: Third mission activities of the two universities.

SDU uses a diversified transfer model, which encompasses all models in Table 4. Importantly though, the university tends to see interactions with industry not as a means to commercialise single inventions coming from the university, but more as a way of nurturing e.g. the drone industry through supporting start-ups and collaborating closely with companies on technology innovation. In this way, the university takes (shared) responsibility for the surrounding industrial partners through an explicit focus on innovation. Projects like ‘Free the Drones’ and ‘Innovation on Wings’ support researchers from SDU acting as partners, especially with technology providers, and collaborating with the drone industry cluster organisation. The university (at research unit level) takes on the role of an “advancer” of innovation within the Danish drone industry and, especially at research unit level, demonstrates an emerging focus on the Ecosystem Model encompassing a systemic model to innovation.

AAU focuses less on the Stanford Model, although the university still seeks to generate at least some revenue from collaborating with companies. The recently established AAU Innovation unit is organised so that it supports students and staff in creating a company based on their discoveries. Overall, AAU is especially focused on the Knowledge Spillover and Collaboration Model, the Spin-out Model, and the Incubator Model. Moreover, AAU envisions that the Laboratory Model would also be an interesting pathway towards revenues, but it is by and large seen in the light of free capacity rather than as a means for industrial collaboration.

Discussion and Future Research

A key premise in this article is the changed purpose of third mission activities – from commercialising single (even componential) scientific discoveries to promoting innovation, e.g. towards Grand Challenges, and how this change demands new third

mission models. But this change also leads us to identify three more general challenges for university management.

A *first* challenge is that series of discoveries may vary across scientific disciplines and the application context, i.e. different models for technology transfer may be needed depending on the application area and the potential market. One can imagine that components for pharmaceuticals demand different transfer processes compared to new and emerging technologies like health technologies for e.g. home care of patients. Especially for the Grand Challenges and the SDGs, the universities need to accommodate changing needs for transfer models – most likely much more focused on relational engagement models. Here, the emerging Ecosystem Model may serve as inspiration.

A *second* challenge relates to the university itself. Most research on technology transfer does not focus on the university as an organisational unit. However, a university is a very complex organisation composed of multiple research units with different agendas, strategies, and research foci (Tartari and Breschi, 2012), and these units are rarely more than loosely coupled through a joint institutional framework (Benneworth, et al., 2016). Contemporary research on e.g. the entrepreneurial university stresses the essence of understanding internal factors within the university as a key strategic challenge to succeeding (Magnus Klofsten, et al., 2019; Siegel and Leih, 2018). Any attempt at gathering research units to coordinate efforts towards addressing a specific Grand Challenge even within one university is a monumental challenge, not to speak of the need for involving cross-university partnerships. Hence, a distinct perspective when addressing cross-disciplinary challenges like the SDGs requires extensive internal coordination even before engaging externally.

A *third* challenge relates to the societal demand for knowledge. Recent perspectives on the third mission of universities emphasise the science commercialisation process as an enabler of change rather than a final outcome (Fini, et al., 2018). Whereas the possible industry partner is known or may be identified in the case of single discoveries, the challenge is far greater with societal challenges as these addressing larger and less well-defined societal actors.

The three challenges point to a changing role of the TTO, where top management of the university becomes more involved while also integrating more extensively with the individual research units that generate the foundational research needed for breeding serial scientific discoveries. Together, these three challenges embrace and form a framework for understanding the following discussion and the implications.

The Ecosystem Model – An Emerging Engagement Model

In line with Barry Bozeman, et al. (2015), our study confirms that achieving the third mission is not only about generating profit for the university but also about interacting with industrial partners, policymakers and cluster organisations to create value for society. By means of a literature review, five third mission models were identified. The empirical investigation confirmed these models and identified an emerging, sixth model, the Ecosystem Model, which provides a thickened perspective on third mission engagement. The results demonstrate in this way that orchestrating third mission models for societal needs like the SDGs is increasingly complex.

Our investigation took as a point of departure that inside a university, opinions on how to achieve the third mission will most likely differ. Two things became apparent from the analysis of the data. *Firstly*, although there are different entities with differing key performance indicators, there is by and large consistency in perceptions across levels

within each university regarding the selection of third mission models. *Secondly*, although both universities describe a shift away from focusing on intellectual property rights protection as the best way to create and capture value, SDU and AAU also represent two different pathways to managing the third mission. The findings illustrate that accomplishing the third mission is not an activity handled solely by the TTO but is a complex set of activities orchestrated across the levels of the university. Indeed, as argued by Benneworth, et al. (2016), a university is a complex mix of research and administrative units, each represented by their own logics, partly autonomous and with different intentions and incentive structures towards the three missions. Hence, third mission models must be initiated and orchestrated with a strategic perspective on exactly these roles, motives and possible effects for each level and actor type. To this end, the current literature on academic entrepreneurship may be useful as a starting point (see e.g. Barry Bozeman, et al., 2013; Lam, 2011).

Grand Challenges and SDGs as Drivers of New Engagement Models

The new Ecosystem Model to the third mission taps into scientific discoveries as the main ingredient for addressing societal challenges. As discussed earlier, the Grand Challenges are mission-oriented and pivot the perspective of the university from inside-out to outside-in, as a demand for technologies and discoveries is stimulated. This perspective further requires new engagement models and develops the existing models by connecting scientific knowledge with missions through collaborative modes (Rinaldi, et al., 2018; Trencher, et al., 2013). The characteristics of the challenges thereby highlight that third mission activities are not only about employing knowledge and research to solve a single need of a single partner, but must also address wider challenges, which require multiple disciplines, research efforts, knowledge integration, and new modes of collaboration

(Knudsen, Tranekjer, & Bulathsinhala, 2019). This combination of mission-orientation like SDGs or Grand Challenges and third mission models has not yet been addressed in the literature and therefore is a theme for future research. As the SDGs and Grand Challenges require serial scientific discoveries, both an interactional perspective and cross-disciplinarity are needed – precisely as seen with the drone technologies – i.e. modular, innovative solutions for emerging markets. No single technology and no single organisational unit can meet these needs. It is our view that future research could investigate the potential of the Ecosystem Model for setting up and addressing either SDGs or Grand Challenges as it has yet to be identified outside the drone technology area studied here.

The Laboratory Model as Facilitator of New Partnerships

The results further highlighted an untapped potential in using lab facilities as engines for collaboration and as possible ‘meeting places’ for new collaborative ties. Although the unused capacity of facilities was recognised as a potential source of revenue, it was not pursued strategically. AAU stated that it could be a potential new revenue stream to exploit the excess capacity of lab equipment. Existing research is also remarkably silent about the possible drivers and barriers to utilising lab facilities as part of establishing new partnerships for scientific discovery, or even innovation. The upsurge of living labs may to some extent serve at least related purposes – see e.g. Evans, Jones, Karvonen, Millard, & Wendler (2015), or more generally Leminen, Westerlund, & Nyström (2012). However, the exact similarities and differences between different lab types must be addressed explicitly. The lab facilities for drone testing at the airport close to SDU is an example of how facilities may be established for creating collaborative spaces, but has yet to demonstrate the nature of the potential. In the more speculative arena, it could be

argued that the physical aspect of the lab facilities as a meeting place can become important for stimulating more collaborative research between industrial partners (if unknown to the research group prior to entering) and the research group. In the case of a super computer, an industrial partner may simply be granted access and use it entirely on a remote basis, as there are no physical aspects to using the facility. However, it is our view that future research should investigate more clearly the possible benefits and barriers to establishing collaborative research based on lab facilities.

Further Suggestions for Future Research

The empirical findings imply that the third mission models are unfolded at different levels and to different degrees within the universities. These different application degrees and their implications have yet to be integrated in the literature on third mission models. At the initial level, this implies that mechanisms across the levels within the university should be analysed, but also how different combinations of models and mechanisms are better integrated towards meeting e.g. a Grand Challenge. Specifically, we suggest that theoretical as well as empirical analysis of the differences in perception and perspective as well as motivation and barriers towards the third mission at various organisational levels within the universities must be better understood in order to devise recommendations for organising the third mission in the future.

Secondly, future research can beneficially take the type of technology or, more broadly, scientific discoveries into account and relate this to the maturity of the related market for the innovative solutions. One may speculate that, like the case of drones, where both technology and market are emerging, there might be more extensive needs for researchers to engage even more closely with industry actors to further the development of the field. As this may imply that the Ecosystem Model is applied systematically to the specific

fields, it also raises the concern that such efforts cut across the university levels and hence require extensive coordination of efforts and instating of third mission models.

Implications for Management Practice at the Universities

Three main implications for management practices at the universities can be identified from this study.

Firstly, universities' TTOs play an important role in achieving the third mission. However, as the two case studies show, the offices may not be the main responsible unit (although they are measured on third mission success by top management). Third mission activities cut across university levels and will often be carried out by the research units at the universities. This implies that the role of the TTOs undergoes significant change and that university management must organise the offices and plan third mission efforts accordingly.

Secondly, the more integrative/collaborative models for accomplishing the third mission could be perceived by some researchers as difficult to execute, if they are not used to and comfortable with e.g. intense company interactions. Therefore, this model seems to be highly dependent on the profiles of the key personnel within the research units. As stressed by at least one respondent, the models require that the university is more explicit about motives, incentives and the coupling (or not) of research and third mission activities. It would potentially be beneficial to formulate incentives and associated performance indicators associated with each of the three missions.

Finally, our research has pointed to the use of lab facilities as a yet unexplored potential for stimulating new collaborative ventures. Whether the university decides to allow or even facilitate access to the lab facilities is likely connected with the adoption of open

science principles as is widely discussed at e.g. EU-level⁶, national level through infrastructure investments by governments, or at the individual university. Based on such lab access, new meeting places for third mission activities can emerge, where the universities invite industry, firms and other stakeholders to come closer to build stronger relationships. Such meeting places for collaboration and scientific discovery may be a new fruitful avenue for leaping into combining third mission activities with societal needs.

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⁶ <https://ec.europa.eu/research/openscience/index.cfm>

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