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Exploring the generic fallacy – meta path-dependencies in innovation-practices of 'drone-making' (eVTOLs)

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Original article

Abstract

Generic technologies are oftentimes heralded as overall beneficial drivers of innovation, especially regarding their flexibility, low cost of adaption (once established) and their inclusiveness toward a variety of actors. This paper adds to literature on innovation-studies by questioning these promises through the lenses of 'lock in' and 'path dependencies' and asks how generic approaches to innovation may contribute to a fallacy where increased flexibility is assumed yet implicitly, a sort of 'lock in genericism' may occur. The paper argues that, for all the advantages that come with the research and adaption of generic technologies, they also bring with them an increased risk of enamourment with innovations that are applicable to a range of potential applications that, in turn, may lead to more specific technological innovations being at the danger of becoming invisible / unwanted altogether. To investigate this phenomenon further, the paper applies the concept of 'lock in genericism' to the field of eVTOL-multicopter- / drone-innovation. In this context, the paper analyzes a series of three case-studies to investigate how this 'lock-in genericism' emerges from material, temporal and spatial components of drone-making and subsequently seeks to outline a framework for 'integrating generic technologies' in this particular field of application (of drones) to overcome the described lock-in in this field while maintaining their advantages. The paper concludes by discussing the relevance of the concept of 'lock-in genericism' on a broader level, highlighting the risk of a 'generic turn' in contemporary innovation practices that, in turn, requires critical reflection.

Keywords

- generic technologies
- lock-in
- meta path-dependency
- drones
- innovation practices

Authors contributions

A – Preparation of the research project
B – Assembly of data for the research undertaken
C – Conducting of statistical analysis
D – Interpretation of results
E – Manuscript preparation
F – Literature review
G – Revising the manuscript

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Introduction: Generic technologies as motors of (drone) innovation?

There is a strong case to be made for the advantages that developing and commercializing generic technologies bring with them [e.g. 1]. Unlike highly particular technological solutions, the application of generic production methods or, more broadly speaking, generic technologies, promises to drive technological advances that are not limited to a single niche and may instead transform entire industries through their wide applicability (see [2]).

While one may easily point to remarkable examples of generic technologies such as transistors [3] that have revolutionized the way we conceptualize and integrate computational resources in our everyday lives, as this paper will argue, there is another, inhibitory side to generic approaches to technological innovation that emerges from this genericism, which is currently not sufficiently explored in the relevant literature. This paper makes the point that technologies – either recognized as generic in effect or projectized as such – are at the risk of becoming tangled up with their promise of general applicability in a way that creates risks for a unique form of lock-in that is characterized by such a technology's increasing resistance to break down into highly specialized applications on a fundamental level which would be, in turn, not commensurable with the overarching promise of genericism.

Furthermore, the paper argues that the continuous reference to generic technologies as universal tools (here: in the field of drone-innovation) may even lead to the increasing dissociation from and therefore conceptual disappearance of highly specific, non-generic technologies all together, as – in contrast to their generic cousins – they may seem too cumbersome and 'not worth the effort'. After all, why would one pick a highly specific solution if another, broadly applicable technology (apparently) works just as well and may be implemented with less effort?

One example for such a generic approach to innovation that exemplifies this issue and that will serve as the prime example for this investigation is the (eVTOL multicopter) drone[i], a generic take on aerial platforms that has spread throughout a considerable variety of fields of application during the last two decades. From light-shows to surveillance, from childrens' toys to agricultural assistants, even from an activist's tool[ii] to the rather elusive 'flying car' or parcel delivery platforms, 'drones' as they are commonly referred to as, on a first glance, seem to have little issue fitting into ever new emerging niches, making them apparently ideal tools for a variety of 'aerial issues' and hereby allowing for their categorization as generic technologies. Unlike other aerial vehicles such as helicopters, the fundamental promise of drone-flight is rather simple – both conceptually and technically: stick four (= quadcopter), six (= hexacopter) or eight (= octacopter) motors on arms to whatever you want to be flying, add a battery-pack, a transmitter and an off-the-shelf flight-controller, depending on the mission, complement it with a GPS, Sonar or LiDAR and after some fiddling with configuration-software, it will be good to go for its first flight! … Or at least that's the latent promise of the 'generic drone'.

The major contributors that this paper has hereby identified as enabling drones as generic technologies break down into material, temporal and spatial categories. On a material level, this includes an increasing trend toward modularity of construction, compatibility with a wide range of off-the-shelf parts, a strong reliance on standardized airframe-designs (usually X- or O-layouts) as well as an inherent connection between drones and (other) digital technologies. On a temporal level, the conceptual simplicity of drones allows for their adaption to a wide range of possible uses in a comparably limited time-frame, which entails that the 'making of drones / drone-making' is increasingly becoming 'no big deal', encouraging experimentation and application. Even if the outcome is not fruitful or favorable, the time spent on such experiments is expected to be rather limited. On a spatial level, eVTOL drones / multicopters tend to rely heavily on a logic of hover-flight that, unlike more traditional aircraft, allows for physical spaces to be re-constructed in terms of geo-fences, Cartesian coordinates and precise flight-vectors, enabling autonomous navigation and overall, a 'digital' logic of movement that is highly commensurable with fields of application such as agriculture, surveillance, photography and others that require aerial movement in particular, pre-defined patterns that would not be compatible with more classic aircraft.

Subsequently – connecting to the argument of genericism as a potential hindrance for innovation – while a variety of applications that are commensurable with the idea of drones as generic aerial platforms (see examples above) have been substantially enhanced by employing drones, others – like that of transport of goods and people, that might demand more particular approaches toward drones (such as dedicated point-to-point travel) – may not have been.

Of course, this (as of now) rather abstract assessment is not the only perspective one could take on regarding the limits of drone-innovation. Previous literature has already investigated potential innovation-hindrances in the field of drone-development: For example, Vinogradov and Pollin [4] argued that certification and overall regulatory constraints may be considered primary factors that hold drone-technology back – as are safety-concern by both professional actors as well as ordinary citizens. While those aspects certainly play their roles in holding back drone-innovation on their own,[iii] it seems that there is something more fundamentally wrong with the apparent disconnect between the promised land of 'drones everywhere' and the failure of plenty such of initiatives that leads to a rather diffuse feeling that something is not quite right with contemporary drone-innovation as a whole and especially when it comes to innovations in the sector of transport-drones. Be it in the form of ever-shifting release-dates[iv] or overall questions of feasibility,[v] the innovation-symbol of 'the drone' seems to have lost a it of its shine during the last years.

It is exactly this rather diffuse feeling that this paper seeks to address: It argues that the apparent slowdown that drone-innovation and -proliferation appears to suffer from (at least in some areas of application) may not be solvable through legal advances, soft-governance or general technological advancements. Instead, this paper argues that the example of drone-technology is indicative of a more general issue associated with generic technologies as outlined above, that leads to a sort of meta-path-dependency where not a particular path emerges as being potentially hindering toward innovation but the way in which we think about the relationship between universal and specific innovation-approaches all together. Specifically, the paper seeks to investigate how contemporary approaches toward drone-innovation stand exemplary for an over reliance on generic approaches to innovation that, instead of driving it, end up slowing and inhibiting more fundamental and disruptive innovative approaches.

To conceptually grasp and, subsequently, practically tackle this issue, the paper first introduces the concept of 'lock in genericism', making the case that generic technologies – as commonly understood – may not only be the solution to lock-in and path-dependencies but may very well create their own, highly particular types of lock-in.

Second, the paper presents its methodical framework, drawing on a combination of grounded theory and real-time technology assessment to both break down the issue of 'lock in through genericism' in three selected cases as well as providing practical guidance on how to overcome this type of lock-in,

Third, the paper sets out to apply these conceptual and methodical frameworks to three case studies of drone-making, highlighting how the innovation-components outlined above (material, temporal and spatial) both enable and disable drones as 'truly' transversally applicable technologies.[vi]

In a fourth and final step, the paper will take the discussion back to a more abstract level, making the case that this example of drone-innovation is indicative of a broader risk for contemporary innovation-practices. Here, it discusses the notion of 'the generic turn' form a temporal perspective as a concept to grasp and critically assess pushes toward generic innovation on a societal level.

Conceptual framework: Generic technologies innovation with or versus the risk of lock-in?

For developing an understanding of the advantages and, subsequently, potential issues associated with generic technologies, this paper starts its conceptual work by building on Shinn's conception of generic research technologies as... "[...] express[ing] some fundamental instrument principle. This permits the research-technology to be general, open-ended and flexible" [3, p. 735] and applying it to the concept of generic technologies in broader terms. From this quote, the two main categories of interest are *open-endedness* and *flexibility*, suggesting that a generic technology is or should be applicable to a wide range of scenarios without, through this application, suffering a narrowing-down in perspective that would inevitably decrease its flexibility / adaptability. Of course, one might make the point that, throughout even a generic technology's maturing, certain aspects that would enable even further increased flexibility or ease of conceptual integration might have to fall to the wayside for the sake of producing more practical technologies. While this holds true in the overall context of technological maturity and implementation [5], this is indeed a first step undermining the open-endedness that may hereby be regarded as essential for 'true' generic technologies. Again, one might argue that this is a necessary sacrifice toward actually making use of a generic technology in practice, however, as will be demonstrated below, it is exactly this creeping decrease in open-endedness, hiding under the veil of such technologies still being fundamentally generic in nature, that may contribute to a shift where genericism drifts from an innovation-driver toward implicitly establishing a restrictive framework of non-open-ended implementation.

Another related concept that highlights the advantages of generic approaches toward innovation is that of 'universal design' as understood by Ron Mace [6]. He argued that what makes a design a universal design is a broadness of (potential) application and its affordance to be easily adapted to a variety of (additional) tasks by with only minor alterations being required for a given design [6]. This conception seems in line with the previously introduced understanding of generic technologies by Shinn [3], if broadness of application is understood as flexibility and the adaptability to (additional) tasks is understood as the open-endedness described above.

One undeniably great advantage that comes with universal design approaches and one that has enabled this approach to design as disruptive in itself is the opportunity for it to satisfy the needs of a broad spectrum of users and therefore to be intrinsically inclusive, both toward users and use-cases. Examples for this inclusivity are numerous and range from designing busses that lower toward the street to allow people with and without disabilities to equally easily board them, all the way to designing barrier-free houses that cater to the needs of a broader range of people than 'normal' houses would [7]. Aside from architecture and urban planning, the concept of 'universal design' has also been applied in a variety of other areas to reflect on and thereby challenge potentially exclusionary design-choices such as, in the example of distance learning, its friendliness toward people with disabilities [8].

In the context of the emergence of generic technologies / universal designs, it is also relevant to point out that designing with an explicit focus on universality in mind is not the only way to come up with (here) a universal technology: As Cowan and Hultén [9] argue, a solution to a given, specific problem may sometimes find much wider application than it was originally intended or imagined for. In that sense, the notion of universal design / generic technologies should be understood not only as an outcome (being universally applicable to a series of problems per design) but also as a framework of implementing initially non-universal technologies across a variety of scenarios (Following the assessment that a given technology or set of technologies has, for whatever reason, emerged as / become rather universally applicable). Therefore, similar to how universal design may not necessarily be the consequence of an intentional, universal design-approach, but instead of a design finding broader application than was first envisioned for it, the emergence of generic technologies may also occur due to similar reasons.

Furthermore, it is interesting to observe that, despite their flexibility and adaptability on their own terms, it seems like similarities attract each other. Here, this means that generic technologies, through their broad applicability, seem particularly inviting for the combination with other, generic technologies. While this will be further expanded on within the empirical work that underlines this paper below, drone-technology and 3D-printing have been identified as being examples for such generic technologies 'sticking together' with the usage of 3D-printing for creating drone-parts having become rather commonplace [e.g. 10–13].

In summary, generic technologies may therefore be understood as technologies that are characterized in the following four dimensions:

a) their ease of adaptability, providing a platform for adaption rather than solutions to specific problems;
b) an affordance toward their adaption with comparably low costs;
c) potential inclusivity toward a wide range of actors;
d) amplification of points a-c by the 'sticking together' of multiple, generic technologies.

Connecting to d) however, this 'self-amplification' that has been observed as resulting from the combination of two or more generic technologies stands exemplary not only for the steady expansion of generic technologies toward ever greater multifunctionality, it also connects to a risk of technological R&D becoming increasingly exclusive toward non-universal approaches of technological innovation. This may subsequently lead to the perceived diminishing of the value of highly specific, tailored technological solutions all together. Due to the enticing and obvious advantages that universal technologies – be it by themselves or in combination with other generic technologies, afford us – it is understandable that, especially in time-sensitive or inherently inclusive operations, generic technologies have their place, however, the emerging drawbacks from this increasing focus on universality in innovation-practices are usually not highlighted in the same way that their advantages are.

Paradoxically, increasing dependence on generic technologies as a primary solution to emerging, technological challenges might actually – and regarding their perceived flexibility, paradoxically enough – facilitate a particular type of lock-in that arises from generic technologies appearing as universal, 'golden tools' and subsequently pushing other, more specific technologies to the wayside as seemingly too cumbersome. To explore this idea further, the paper uses the definition of Lock-ins, as presented by Cantner and Vannuccini who understand lock-in as "[...] a deadlock of technological competition or economic dynamics, where one of the competing alternatives – not always the superior one – becomes uncontestable" [14, p. 11] .

When it comes to the concept of generic technologies however, there is a bit of a twist: as outlined above, universal technologies necessarily transcend specific alternatives, unlike, for example, in the case of the QWERTY-Keyboard (a common example for technological lock-in) and are instead defined by their platform-like characteristic to fit into a variety of scenarios and niches. Therefore, they are not susceptible to lock-in on the same level that, for example, the development of QWERTY-keyboards and their (lack of) alternatives are. In contrast, generic technologies necessarily transcend particular choices or determinations for their application that, when repeated sufficiently, usually contribute to the phenomenon of lock-in ([15] – here, regarding path-dependencies) for non-universal technologies.

Consequently, what puts generic technologies at a particular risk for experiencing lock-ins is not the pay-off that is associated with sufficient people continuously using a given technology in a highly specific context [16] but the risk of becoming too enamored with generic approaches on a meta-level and therefore also becoming increasingly blind toward the possibility that the perpetual application of universal technologies may in itself cause a limitation in perspective and hence a limitation in flexibility and open-endedness that those technologies promised in the first place. 'Locking in generic technologies' hence does not occur in particular applications themselves but in the conceptual framework of how we think about tackling given problems all together – what tools we apply or how we conceptualize technological solutions. Instead of thinking of specific problems as problems that, in turn, might require specific solutions or would at least afford thinking about addressing them in a rather specific ways, a 'lock in of genericism' may lead to the increasing conceptual disappearance of specific solutions all together and an 'adapting the problem to the (generic) technology' instead of adapting technologies to problems.

Another way of thinking about this type of lock-in is through the concept of path-dependence. While, as Cantner and Vannuccini [14], in referring to Gallagher [17] argue, on a meso-level, the concepts of path-dependence and lock-ins largely overlap, in the case of lock-in through genericism, the concept of path-dependency adds to the understanding of the issue at hand when conceptualized as a kind of meta-path-dependency. As generic technologies are exactly this, generic, they defy lock-in in a particular niche or in one specific application. However, the concept of path-dependency does sensitize for the 'hidden specific' that accompanies technologies in general and, in this context, also generic technologies: By being applicable to a wide range of scenarios with only minor design-changes being required (see point a – ease of adaptability / platform-character), such technologies tend to hide the presumptions and, paradoxically, the highly specific design-choices that enabled them as apparently generic technologies in the first place. In this sense then, when applied to a 'lock in genericism' the concept of path-dependency 'goes meta', beyond the dependency on one development-path or the intersection of various such paths and instead allows to highlight how a technology's openness to a variety of paths on a meta-level hides highly particular, potential applications away that it is not commensurable with. This is exactly where a lock-in genericism occurs: Not in a particular technological niche but in the lack of niches that would challenge the universal technology and its implicit presumptions all together. It is this very mode of technological lock-in that occurs hidden under the presumed mask of 'impossible to lock in due to its universality' that makes universal technologies, paradoxically enough, especially vulnerable to them.

Methodical considerations: Participants' video-accounts of drone-making

Prior to further expanding on drones as examples generic technologies, this section provides a short summary of the methodical framework this paper operates within. The empirical starting point for this paper consisted of extensive ethnographic fieldwork conducted amongst a variety of actors in fields of drone-innovation, including both commercial actors[vii] as well as non-commercial actors (see below). Throughout this fieldwork – following a constructivist, Grounded Theory approach [18,19] – the notion of 'Innovation hindrance through perceived technological omnipotence' was developed and, through the subsequent collection and review of relevant research was refined toward the notion of 'Lock in genericism'. This concept, as introduced in this paper, is to be understood as a theoretical contribution first and foremost, however, it also makes a strong case for its practical implications in (here) the field of drone-innovation and, further below, proposes an integrated innovation-framework to counter this type of lock-in. Therefore, despite this strong conceptual focus and in line with Schot and Rip's constructive take on technology assessment, this practical component may be formulated as: "[...] to reduce the human cost of trial-and-error learning in society's handling of new technologies, and to do so by anticipating potential impacts and feeding these insights back into decision making, and into actors' strategies" [20, p. 251].

However, considering the counter-intuitive nature of the phenomenon this paper seeks to study, methodically, this paper is more closely aligned to Guston and Sarewitz's variation of T.A. (Real Time T.A.) which emphasizes potential issues with technological foresight and instead highlights socio-technological interdependencies and the subsequent inaccuracies in planning that might arise. As they put it, "[...] real-time TA is necessary precisely because planning and perfect foresight are illusory" [21, p. 109].

Of course, this statement should be taken with a grain of salt as, like other forms of TA, real time TA aims at improving innovation-processes and is therefore necessarily directed toward the future and subsequently also includes planning and foresight. Still, what real time TA promises to offer is a more realistic – one might say a more 'messy' – approach toward assessing technological innovations that acknowledges the co-produced nature of, for example, developing (legal) frameworks for future innovation, emerging R&D trends, changing perceptions, changing means of knowledge-sharing, potential societal impacts and so on [21]. As a whole – both conceptually and practically – this paper hereby draws on the methodology of this variation of T.A. in particular, as it seems best suited to explore the phenomenon of 'lock in through genericism' due to its presumed roots in the interplay between technological resources, practitioners' expectations and the knowledge they refer to.

Subsequently, this paper fundamentally adheres to the research plan as outlined four central by Guston and Sarewitz [21]:

1. The analysis of analogical case studies.
2. The mapping of resources and capabilities of innovation-practices to identify R&D-trends, participants and their roles.
3. Eliciting and monitoring changing knowledge, perceptions, and attitudes among stakeholders and identifying early warning signals.
4. Engaging in analytical and participatory assessments of potential societal impacts

The analysis will hereby be conducted in two steps: first, it investigating case-studies taken from examples across the 'realm of drone-making', ensuring that the analysis provides reliable results beyond a single niche of drone-innovation. Secondly, as a summary of these case-studies, the paper will provide a map of some of the resources and capabilities currently associated with the field of drone-innovation, as derived from the case-studies and additional fieldwork.

Regarding the case studies at hand, instead of referring to some of the numerous examples from previously conducted, ethnographic fieldwork, this paper instead picks primarily from participants' own accounts, as shared in the form of online participatory videos (here) on the platform YouTube. Especially for a technology that is inherently digital and that may therefore be considered as especially compatible with diffusion through social media as well as one that commonly incorporates a strong, (audio-)visual component,[viii] investigating practices of drone-innovation may particularly benefit from considering not only classic, ethnographic means of data-collection such as researcher-centric, ethnographic accounts or interviews but also participants' direct accounts. Aside from the obvious advantage of 'conserving' the particularities of (here) practices of drone-innovation, using participant videos as data-source also allows the contrasting of innovation-practices between online publics, hereby enabling a more reflexive perspective. In this context, this paper builds on the method of 'online participatory video analysis' (OPV-analysis) as first proposed by Schmidt and Wiesse [22], which, in turn, followed Tuma's work on (expert) video analysis [23,24] and more classic videoethnographic approaches such as summarized by Redmon [25]. While this is not a main focus of the paper, it also includes elements of IOPV-analysis [26] which entails an expansion of the data-material sourced from OPVs to not only include audio-visual material itself but also context-information about the public it was posted within. This includes both background information (such as previous uploads by a given user / channel) as well as the context that is being created through participation, like comments, video re-mixes, video responses, etc. In the context of the three case-studies below, this aspect is limited to temporally-disconnected means of community integration [26], highlighting some comments that stood out in terms of their contribution to the case-studies.

Empirical work: Components and cases of drones as (too) generic aerial vehicles

As a starting point for the subsequent analysis of current challenges in the field of drone-innovation and – by extent – in contemporary innovation-practices with a focus on generic technologies as a whole, it is necessary to first precisely define the main object of the study. In fact, this first step already gives attentive observers a first peak into the foundations of 'the generic drone' as drones present themselves as artifacts that seem to require little definition in the first place. The term 'drone', by now, seems to have become equivalent to the symbol of a cross with four circles surrounding it.

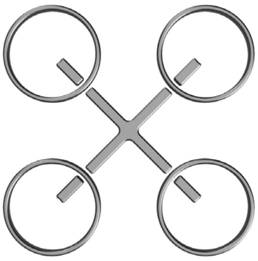


Figure 1. The symbolic drone

This symbol (Figure 1) is more than a low-fi representation of the associated technologies, however – like motors on sticks: 'Drones' have become representatives of highly generic tools that we, albeit implicitly, refer to in terms of the universality of their application. For example, building on this implicit understanding, as mentioned above, Vinogradov and Pollin [4] were able to, in quite substantial detail, elaborate on the previously summarized, contemporary hindrances of drone-innovation without once explicating their understanding of the term 'drone' in the first place. What might be considered a simple oversight in other cases, when it comes to the drone, is indicative of how generic our understanding of them has already become. Saying 'drone' only loosely refers to a specific set of technologies – instead, it means a way of flight, a particular logic of putting things into the air that is common for 'drones', so common in fact that it does not seem to require any additional explanation. In the context of this study then, simply saying 'drone' would be enough to make the whole point of the paper as it already implies an over-simplification that is constitutive and therefore also restrictive for their creation and usage.

For the sake of accuracy and for the differentiation toward what one might consider atypical drones (in the context of drones as generic aerial platforms), the term 'drone' is hereby used for electric, VTOL capable multicopter-aircraft first and foremost. While there is a case to be made to expand this definition to also include non-electric, non-VTOL-capable or non-multicopter-aircraft,[ix] this paper primarily focusses on drones as the 'start-and-land-anywhere, electric multicopter' that most people associate with drones today and that has made it into such an iconic symbol of contemporary innovation in the first place.

Following this definition of drones, the subsequent three main components have been identified as contributing to making drones into the generic tools we see them as today. Those have been derived first and foremost from the (I)OPV-analysis of several hundred drone-related videos, ethnographic fieldwork in a series of (four) 'drone-making' workshops as well as accompanying several cutting edge R&D-projects on drone-innovation. Furthermore, regarding material factors that have and may furthermore enable generic drone-innovation, a review of the relevant scholarly literature has been conducted. As of now, the other two components of drone-making below (spatial and temporal) have not been explicated in the relevant literature to the same degree as material factors, hence the stronger reliance on empirical work in these instances.

These three, primary components are:

1. MATERIAL: **Modularity of drone-construction, parts' availability and simplicity of construction-frameworks** (These are also common characteristics that comes up in literature on drone-making [10,27,28]. This also includes their inherent **compatibility with digital technologies and A.I.** [29,30]
2. TEMPORAL: **Instant availability of knowledge** of drone-making, **short development-cycles**, commensurable with **frameworks of rapid-innovation** and contribution to drones as technologies **well suited for applications with temporal restrictions on development-periods**.
3. SPATIAL: **'Digification' of flight areas**, where a strong reliance on hover-flight as primary mode of locomotion leads to a **reconstruction of flying spaces into static spaces of flight, highly compatible with waypoint-dependent missions** and **overall non-dynamic movement** (in contrast to traditional aircraft).

Of course, these three components do not occur independent from one another – for example, the compatibility with digital technologies (1) obviously relates to (2) insofar as this compatibility also implies creating a spatial framework in which this compatibility is achieved. Another example for such interdependencies would be how the reliance on a particular way of space-making (i.e. hover-flight) also leads to a shortening of development cycles in terms of flight-controls from other hover-drones being able to be re-used. Consequently, this distinction should be understood first and foremost as a heuristic for examining the impacts of generic technologies and not as a strict system of independent categories.

Furthermore, one may argue that these components are not only material, spatial and temporal but also, on a higher level of abstraction, insofar inherently social as they shape the way in which practices of drone-innovation may be imagined in the first place. However, for the purposes of this study, each of the three case-studies to be investigated below highlights one of these components above. The before mentioned interplay between those components will be highlighted at some points in those cases, it is however not an explicit focus of this study.

Connecting to the previous introduction of how these three components may be understood as enabling drones as generic technologies, the following case studies seek to investigate the validity of this statement. Here, aside from highlighting how, specifically, this 'enabling genericism' occurs, the study puts a trong emphasis on the drawbacks that come with this 'enabling' that, as this paper argued above, are commonly overlooked. Therefore, none of the following case-studies should be understood as inherently bad examples of drone-innovation. Those examples were chosen because each of them demonstrates both advantages and disadvantages that come with conceptualizing drone-innovation as a (largely) generic process and how both of these sides are interwoven in practice.

Case 1: Material components of a lock-in drone-genericism

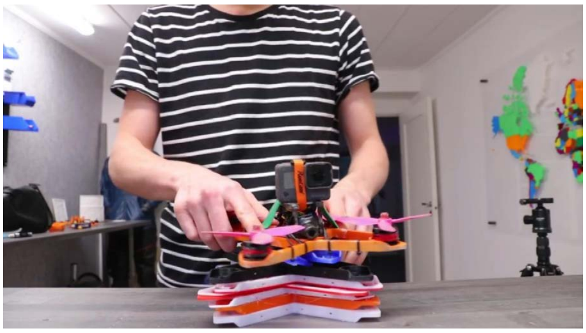


Figure 2. Mounted polypropylene-frame on top of previous test-frames (10:54)

The first case study this paper investigates in the context of eVTOL multicopters as generic technologies highlights the material components that contribute to drones emerging as such generic technologies as well as critically assesses how these same material aspects contribute to a 'lock in genericism' as described above. The video itself stands representative for a substantial community of 3D-printing- and multicopter-enthusiasts (including the author of this paper) that employ 3D-printed drone-frames and other parts in their aerial vehicles, hereby combining two generic technologies: 3D-printers and drones.

This particular participant account tells the story of a YouTuber named "RCLifeOn",[x] a comparably large channel with around 860.000 followers, searching for suitable materials for a 3D-printed drone frame that would not break under normal use (including occasional crashes). In this context, it is noteworthy that the same channel also published a variety of other videos focusing on 3D-printing technology in the past, such as "5000W Motor In a 3D Printed Jet Boat"[xi] or "5kW Electric Snow Racer Made With 3D Printed Parts".[xii]

The video selected for this case study, is titled "A Flexible 3D Printed Drone That Can't Break",[xiii] was uploaded in March of 2020 and, since then, has garnered around 410.000 views and 21.500 likes. In a nutshell, this video tells the story of 'RCLifeOn' testing and breaking a series of drone-frames printed from various thermoplasts. After a series of tests, a drone-frame made from Polypropylene came out as withstanding multiple crashes and was therefore deemed superior to the other materials used (TPU, PETG, PLA and Nylon – Frames seen in Figure 2) in this application.

First and foremost, the advantages that come with 3D-printing drone-parts are obvious and should not be understated: With a 3D-printer and the necessary CAD-software / Slicer, one may design drone-parts or even entire, flyable drone-frames, as demonstrated by the flight-tests in the video, throughout the four 'Build your own Drone'-workshops mentioned above[14] and in the numerous research-papers that have already explored the connection between 3D-printing and drone-building (see above).

The disadvantages that come with this approach to creating drone-parts and that, ultimately, contribute to the described 'lock-in genericism' is exactly this enticement that culminates in a contemporary '3D-print the world'-mindset. Aside from inherent limitations of scalability, part strength, part weight and part stiffness of (DIY-FDM) printed parts – the latter becoming especially relevant for more aggressive PID-tunings - the most substantial drawback that 3D printed drone components bring with them is the invisible restriction on how (materially) drone-making should be conducted in the first place. If, on the surface, 3D printed parts somewhat work, it becomes difficult to – for every emerging problem or new part – not immediately refer back to 3D-printing as primary means of production. Connecting to the drone-workshops that used printed frames, despite the clear limitations that became painfully apparent through a whole stack of broken drone-frames (Workshop 2), the eventual solution still only seemed one print away – 'Just a matter of design! – 3D printing is usually the solution, so it must be here too, right?' While proper (printer-friendly) design is obviously part of the solution, it is also part of the problem: the perceived creative freedom that comes with

DIY FDM-printing further enhances the notion that the issue cannot possibly lay with the means of production itself but, once the right design was found, all issues would – by the power of 3D-printing – magically disappear. Instead of accelerating innovation, the oftentimes painful process of slowly figuring out that, despite all the hype, a given part may not be 3D-printable after all has been observed to contribute to slowing drone-innovation. Therefore, what connects RCLifeOn's search for a proper material to print drone-frames of, the conducted drone-making workshops and various student initiatives where 3D-printing always sat right on top of the list of desirable means of production is the latent belief that – through communal reproduction – drone-making and 3D-printing are a priori connected.

Of course, one could argue that there are some drawbacks with any means of production, be it 3D-printing, CNC milling, composite-lamination or any other. However, what puts 3D-printing at a particular risk of enabling a lock-in genericism are exactly this apparent general applicability and availability that, in turn, implicitly re-frame drone-innovation from a process that requires suitable means of production to a process where innovation needs to conform to this generic logic of production. Here, the before mentioned attraction between generic technologies comes into play: whereas other means of production more obviously incur specific limitations, the limitation of (here) 3D-printing is the apparent lack of such specific limitations, implying that there is no reason for why one would not simply 'print a drone' and hereby subscribe to and contribute to a mindset of generic innovation / production that is necessarily exclusive toward more specific solutions and therefore to more radical innovation.

Case 2: Temporal components of a lock-in drone-genericism

Figure 3. Day seven: TMS dives his drone down the side of a snowy cliff (15:06)

Whereas the first case study presented above highlighted some of the material aspects that may contribute to a 'lock in genericism for eVTOL multicopters', this second case study focusses on the temporal framework of their development. The participant video that was selected as exemplifying this component was uploaded by the YouTuber "TMS Productions" (~156.000 subscribers) and documents his attempt at building and learning to fly a FPV-drone for filmmaking purposes within only one week. Already in the title of the video, "Learning to FLY a CINEMATIC FPV DRONE in ONE WEEK!"[xv] (860.000 views, 22.100 likes), a clear focus has been put on highlighting the time-frame for this experiment.

TMS himself hereby describes his motivation behind this initiative as:

0:23 "Now, unless you lived under a rock for a while, you've probably seen one of these guys [holds up FPV drone]. This is called an FPV racing drone [Note: One would not race with a Go-Pro – it's more like a freestyle drone] and it is by far one of the coolest things that's just kinda taking the filmmaking-world by storm. The crazy thing about these guys is that you can get shots that you never thought you could have ever gotten before. Take a look at this shot" [drone-footage of people on skis mid-jump follows].

Throughout the entire video, this one-week timeframe seems almost comically short, especially when TMS, in contrast, describes how the mere delivery of the required parts "took about a month for everything to arrive in the mail" (1:30). While he did add that he conducted extensive research on the components and skills he would require (1:13) for this task before the week of building and flying started, he emphasized that this was his first drone-building experience and that he had no prior experience in this field aside from flying a standard DJI drone. Despite this preparation, the phase of building and learning to fly the drone itself only extended across one week. At the end of those seven days, he completed his goal to dive it off the side of a cliff (Figure 3), recording this flight.

First, it is necessary to emphasize the impressive results this video demonstrated – Both in terms of the pilot / filmmaker's dedication as well as the comparably simple operational framework modern drone-making affords. However, by emphasizing this 'build fast, fly fast' framework, an inherent hostility to more time-intensive, innovative approaches that do not follow this framework and might require longer development cycles may emerge. An impressive example of this came in the form of a recent interview, conducted with the chief organizer a local Drone-Innovation-Incubator – Here, it was pointed out that it took them a long time to realize that 'coming up with a new flying machine is not the same as just conducting a hackathon', referring to the develop-fast, implement-fast-mindset associated with such short-time formats. While they definitely have their place in areas such as the development of exclusively digital products and have hereby yielded impressive results, transferring this logic of development to other fields may lead to too high expectations and, subsequently, a trend to rather limit the idea itself than to extend the temporal framework beyond what has been internalized as being adequate. This issue hereby applies to the field of drone-making in particular due to its substantial, digital components that seem to invite the beforementioned hackathon-mindset of creating innovative products in a very restrictive timeframe.

Moreover, compressing the time-frame available for such development also entails a necessity to stick to established practices, creating co-dependencies toward the material aspects outlined above and the following, spatial framework of innovation. While this was not problematic in the context of this video – as the pilot / filmmaker clearly pointed out that his goal was not radical innovation but re-production of a drone-dive – these temporal restraints may become an issue when directly aiming toward introducing innovation to drones where the goal may not always be a mere re-production but rather the iteration on or even overcoming of established drone-making practices. Therefore, in line with the material limitations of drone-making outlined above, the issue with the video by TMS does not lay with its particular outcomes, as those were rather successful, but in the narrative of drone-creation it drives.


damian gasparac vor 2 Jahren
The most stupid thing in this hobby is impatience.
1585 ANTWORTEN
27 Antworten ansehen

Figure 4. 'Stupid impatience'

One highly upvoted comment underneath this video by TMS Productions highlighted this very issue (Figure 4) – of course, while one might argue that impatience is a poison to taking on any new hobby, the temporal framework of 'making drones fast' may further feed this impatience, not only when it comes to a hobbyist's approach toward drone-making but also in professional contexts and therefore to the setting of deadlines and expectations of how quickly success should be achievable. Connecting to the interview mentioned above, this may lead to innovation-environments that are highly conductive to small improvements / iterations of this basic framework, yet hostile to more radical innovations, hereby sticking with generic approaches toward drone-making without necessarily questioning the latent presumptions of why this generic framework of innovation is being continuously reproduced in the first place.

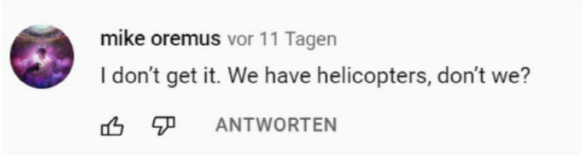
Case 3: Spatial components of a lock-in drone-genericism

Figure 5. Air One in Hover Flight (0:34)

Before a detailed analysis of how the spatial framework employed in this case-studies both enables and inhibits the eVTOL PAV[xvi] in this example is conducted, it is important to point out that the issues to be described in this example are by no means exclusive to the "Air One" – far from it. In fact, be it the Bellwether 'Volar', Airbus 'City Airbus', Volocopter 'Volocity' or others, many first flights of PAVs as well as, usually, subsequent flights, operate in a very similar framework to what is being shown in this video. The video[xvii] ("AIR ONE eVTOL Full Scale Test Flight") of this particular first flight has been posted by the official YouTube channel of "Air EVTOL",[xviii] the creator of this PAV and was performed in July of 2022. Here, the "Air One" has been tethered to the ground with a chain (See Figure 5) and the flight itself merely consisted of a short period of hover a couple meters off the ground. As of now, this rather new video has garnered around 47.000 views and 263 likes, which is substantial, regarding the very limited subscriber-count of the channel it was posted on (~1400 subscribers). While this 'first flight' has been titled as such and the subsequent celebrations at the end of the video suggest the reaching of a large milestone, it seems odd that 'flight' has already been considered achieved practically without any substantial lateral movement. This is particularly interesting when taking into account that the aircraft in question is a hybrid of a fixed-wing and a multicopter, which, unlike the 'classic' drone-layout that does not integrate any substantial, non-rotating, lift-generating surfaces, becomes more energy-efficient in forward flight. What this video exemplifies in the context of this study, is a trong reliance on 'hover' as the primary framework of operation for (e)VTOL vehicles, even, such as in this case, PAVs. In a 'behind the scenes' of the Air One,[xix] Air CTO and Co-Founder Chen Rosen highlights the transfer of drone-technology from, for example, camera drones to the application of eVTOL PAVs, also explicitly referring to the "ease of flight," as highlighted in the case study above: "It just all came together [–] at a certain point you understand that the simplicity of drones and the ease of flight that we are already used to from camera drones, for example[:] if we can combine that into an an aircraft that carries people, then again, this will make things a lot more approachable, a lot more easy to use, at lower costs that existing aircraft" (0:35 –1:02).

Despite this framework of operation having proved highly useful in many other cases where a digital logic of flight is required (such as following a pre-defined, tight and comparably low-speed flight-pattern), this contemporary take on conceptualizing eVTOL-vehicles as hovercraft first and foremost necessarily limits the ways in which we think of their operation. In the context of eVTOL PAVs, where the framework of spatial operation may be assumed to be more akin to a point-to-point transfer than to hover-like movement over a pre-defined grid of waypoints, the usefulness of employing a hover-framework first and foremost is rather questionable. Of course, there is something almost magical about 'having your vehicle sit motionless in the sky', however, an increasing focus on this kind of locomotion – or rather non-locomotion – necessarily restricts how we understand 'flight' and how or whether we critically reflect on the value of this established framework across a variety of scenarios at all. Similar operational frameworks have been identified in one drone-innovation-challenge that has been attended as a part of the ethnographic fieldwork for this study where the promise of 'innovating toward PAV-flight' (as point-to-point transport of goods and people) was systematically (through very strict limitations in permissible flight-space) reduced to minimal lateral movement. In both that drone-innovation challenge, as well as this OPV case study, the a-priori employment of a spatial framework of hovering means necessarily limiting how we conceptualize dynamic PAV/UAV-flight as a hole and therefore also how or whether we approach frameworks of flight that are more dynamic than hover-flight[20] and therefore not necessarily compatible with established control-routines, etc.

As a final note on this first flight presentation, there were about an equal number of comments underneath the video that commended the engineering team on their milestone and that criticized the flight for not being very impressive. One particular comment by "Mike Oremus" (Figure 6) stood out however, as it highlights the spatial logic underlining the operation of this first flight.



mike oremus vor 11 Tagen

I don't get it. We have helicopters, don't we?

Figure 6. 'We already have helicopters'

Here, the commenter draws parallels between helicopters and the Air One which could be interpreted as questioning the necessity for re-producing a helicopter's logic of flight 'in a new shape'. Of course, there is a strong case to be made for the reduced complexity and, therefore, the reduced operating costs that (usually) come with eVTOL multicopters, when compared to much more complex helicopters, so, on this level, the comment is a bit inaccurate, especially considering the already broad application of eVTOL multicopter in other areas (also, see Chen Rosen's statement above). However, this comparison does sensitize to question exactly this spatial framework of operation, as outlined above. The framework of hover, while being well suited to helicopters due to both the employment of traditional, high-constant output powerplants as well as a larger diameter rotor when compared to multicopters, may not be the best approach for transport eVTOL multicopters. Still, in consequence, the contemporary reliance on exactly this framework could mean that other frameworks of flight are becoming increasingly invisible, further adding to the sense that 'there is no way around hovering.'

Summary: Generic technologies as innovation-motors and -hindrances

This paper explored the concept of generic technologies in the context of hindrances toward technological innovation. It hereby introduced a counter-perspective to the oftentimes one-sided understanding to such generic technologies as highly valuable drivers of innovations. The paper connects to the literature on innovation-research by acknowledging that such technologies do have their merit and allow for innovations to spread much more quickly from one field to another, limiting the risk of lock-in as it is usually understood. However, it adds a new perspective on generic technologies by highlighting that they also bring with them a series of potential risks of limiting innovation that should not be overlooked. It hereby argued that using generic approaches to innovation does not necessarily limit the risk of lock-in of a technology but that it, instead, creates a unique vulnerability toward a particular type of lock-in: A lock-in not *despite* but *through* genericism. This vulnerability has been identified as being associated with generic technologies insofar as they may both hide associated particularities under a veil of apparently universal application as well as leading to a dismissal of more specific innovations due to their advantages in terms of accessibility, adaptability, inclusivity and openness to combination with other, generic technologies.

Using contemporary practices of drone-making as an example, the paper highlighted three components of how generic innovation approaches may contribute to this type of lock-in, that in this context, has also been described as meta-path-dependency. Those components and their enabling, respectively inhibiting aspects toward drone-innovation have been summarized in Table 1.

Table 1. Components of drone-innovation

Component	Enabling Aspects	Inhibiting Aspects
Material	Modularity, Ease of fabrication / assembly	Lock-in(to) highly specific production-methods
Temporal	Rapid implementation and adaption	Incompatibility with long-term development cycles
Spatial	Hover-based conception of flight highly compatible with digital controls	Inhibitory in regard to more efficient, dynamic flight-envelopes

While each case study above was chosen to present one of those three components, it is furthermore important to also consider potential intersections of emerging effects of meta-path-dependencies between those categories. Below, some aspects from these case studies (as well as additional potential path-dependencies from the speculative concept of 'integrating generic technologies' as well as further fieldwork) have been summarized in a 'Map of eVTOL multicopter innovation' (Figure 7), highlighting (from inside to outside) established, (generic) means of 'drone-making' (inner circle), uncommon means of 'drone-making' (mid-circle) and rarely if ever implemented means of 'drone-making' (higher integration; outer circle). This map should hereby sensitize for how the continuous reference to established practices of 'drone-making' in the inner circles is necessarily exclusive of other practices 'out there' that, in turn, may substantially limit innovation-imaginaries in 'drone-making' as a whole. As already highlighted prior to and in the case studies above, these established means of 'drone-making' are not to be demonized in any way. In fact, they have significantly contributed to the ongoing spread of drone-technology, however, their impact should not be generalized as a given in every branch of 'drone-making', nor should they be blindly employed which might cause clouding the view on potential breakthroughs that are not commensurable with such generic approaches.

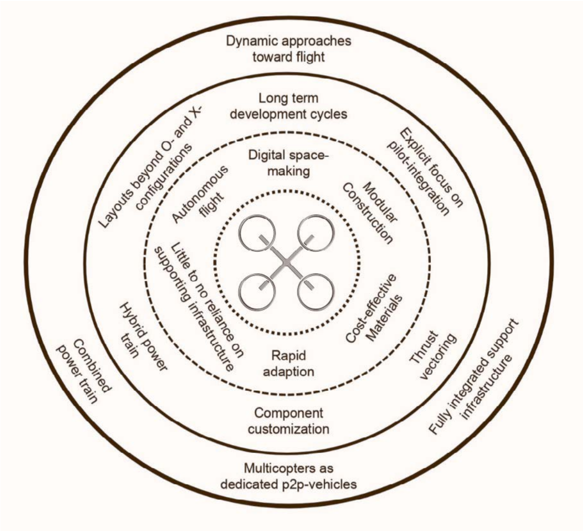


Figure 7. Map of contemporary building blocks of eVTOL multicopter

Discussion: The Universal Turn?

In this last section, the paper will reflect on how a continuous spread of universal technologies and – as demonstrated in the case of the drone – the increasing conceptual reliance on them when it comes to innovation-practices, could influence conceptions of technological innovation on a broader, societal level. While one might easily argue that the development toward universal technologies – as outlined above – should merely be considered a fringe-phenomenon or a phase in contemporary innovation-practices that may soon be superseded by a phase of more specific innovation-practices, there is a point to be made that this might not be the case and that there is something more fundamental to this increasing reliance on generic technologies and generic approaches toward innovation as a whole. In this outlook, the paper motivates a time-sensitive perspective to discussing potential reasons for this trend that could be understood as a 'universal turn', hereby connecting to case study two above.

Following a rather classic approach toward technological proliferation (for an overview, see [31]), one could argue that, with the ever-increasing spread of available technologies (also through increasing, digital components), their application and the associated spread in complexity, the trend toward universal technologies represents an attempt at reducing this very complexity. Following the definition of universal technologies as represented above, the opportunity to apply a given technological framework to an increasingly diverse set of potential use-cases would entail a imitation of technological alternatives that need to be considered, which would especially benefit innovation-practices in highly time-sensitive contexts. When following this line of thought, one may argue that, in a presumed future of ever-increasing complexity, the reliance on such innovation approaches may further increase. Here, the role of generic technologies could be considered one that is not simply a 'nice to have' anymore but could become mandatory to keep up with the promises of continuous, rapid innovation.

Such promises are exemplified in participatory formats such as Makeathons or Hackathon – formats [e.g. 32,33] that commonly aim at developing a product from a first idea to a working prototype within a highly restrictive, time frame. Aside from single events, this 'Hackathon-Logic' may be considered indicative of a more general, contemporary approach toward innovation that prioritizes fast iterations and fast development times over the time-consuming development of dedicated technological solutions. A similar trend, albeit more abstractly, is also exemplified in agile approaches toward manufacturing as a whole [e.g. 34,35] that have gained substantial traction during the last decades.

Concluding this short discussion, it is as of now impossible to definitely answer whether or to what degree the developments outlined above merit the diagnosis of a 'generic turn' in contemporary innovation-practices. However, it is obvious that, in certain fields and spaces of innovation (For example, eVTOL-multicopters and makerspaces), there is a substantial reliance on generic technologies and the frameworks of innovation they establish that, especially when it comes to the fringes of their practical applicability (such as the construction of a 'mostly 3D-printed CNC-router',[xxi] start becoming hindrances of innovation instead of its driver. Therefore, for all the advantages that generic technologies have brought and will continue to bring with them, we should tread carefully, watching out for the hidden beliefs behind these apparently agnostic technologies and when implementing them, critically assessing the frameworks of innovation we import alongside them.

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Endnotes

i The term ‘drone’ is hereby used as already implicitly referring to a generic framework of operation. Throughout extensive fieldwork and literary analysis, when using the term ‘drone’, most actors implicitly refer to a generic take on aerial vehicles. Of course, while some non-generic drone-designs do exist (such as flying wing designs and many more), the paper focuses on ‘drones’ – technically ‘eVTOL multicopters’ – as this both seems to be the common association actors draw when talking about ‘drones’ as well as due to their inherent limitations, as discussed in this paper.

ii For example, see: https://www.theguardian.com/world/2015/apr/22/drone-with-radiation-sign-lands-on-roof-of-japanese-prime-ministers-office.

iii For example, the current legislature for unmanned aircraft systems by the EASA does not allow for items to be dropped from such aircraft unless they serve agricultural, horticultural or forestry purposes (see AMC2 Article 11 Rules for operational risk assessment, page 125 at: www.easa.europa.eu/downloads/110913/en), necessarily limiting the innovation-potential in, for example, the context of parcel delivery.

iv Such as, for example (but by no means limited to) the recent announcements by Lilium: https://www.electrive.com/2022/04/04/lilium-postpones-market-launch-until-2025/.

v For example, multicopter-technology for package delivery. For a comprehensive literature review [36].

vi Here understood as technologies that are generic in nature yet able to ‘break down into specifics’ and therefore fulfill the promise of adaptability.

vii Examples include participatory observation in a ‘Drone Challenge’ by a major European aerospace company as well as online-ethnography of another such ‘Drone Challenge’ by a major US aerospace company

viii Examples include aerial photography, surveillance, FPV-flight and others.

ix Examples for the former include aircraft with hybrid or traditional power trains; Examples for the latter include increasing popular, compact flying wing designs

x https://www.youtube.com/c/RcLifeOn.

xi https://www.youtube.com/watch?v=WhMKUmSEGPo.

xii https://www.youtube.com/watch?v=lPUgdD31yqg.

xiii https://www.youtube.com/watch?v=Ix4EnU-sATQ.

xiv While the third and fourth of these workshops did eventually use standard drone frames, cut from carbon fiber sheets, the first and second workshop used 3D-printed frames that (despite being printed from PETG which has been established in case one as being inferior to Polypropylene in this particular application) held up to minor crashes and that were significantly improved in-between the first and second workshop. While this creative freedom and the frame’s adaptability have been substantial advantages, the constant breakage of these frames by the rather inexperienced participants lead to this shift toward standard, carbon fiber frames.

xv https://www.youtube.com/watch?v=yqkzYAmbdwc.

xvi PAV, in contrast to UAV (=unmanned, aerial vehicle) stands for personal, aerial vehicle. This term has gained popularity in the context of ‘new, aerial mobility’, as commonly associated with a shift toward ‘flying cars’ or ‘air taxis’. The term PAV has hereby been chosen, since it does not limit the frame of operation like, for example, the term of UAM (urban, aerial mobility) would. In the context of multicopter-innovation, this is relevant because thinking of PAVs as UAM-vehicles limits their operational framework on rather short flight-distances which is not conducive to a more general approach to multicopter-innovation.

xvii https://www.youtube.com/watch?v=2IdgzSnswOY.

xviii https://www.youtube.com/channel/.UCjD8Me28M91f_R04Zmmkv2Q.

xix https://www.youtube.com/watch?v=1g5gLNfV--o.

xx While there have been attempts to co-design aircraft and their operational frameworks [e.g. 37,38], such approaches are, unfortunately, far less common than (research-)drones that operate in the true and tested hover-framework.

xxi This example has been taken from extensive, ethnographic fieldwork in a Bavarian Makerspace. Here, the Makerspace’s organizers set out the goal of building and using a ‘mostly 3D-printed CNC-router’ intended for the usage with soft materials such as wood or foam blocks. While the advantages here are obvious (accessibility, low costs, modularity of construction), the router had substantial issues with structure flex and stepper-motors losing steps, leading to inacceptable inaccuracies (>1 mm) in the milling process, that could be traced back to the 3D printed construction.