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Distributed Manufacturing of Open Hardware

A Report of the Open Hardware Distribution & Documentation Working Group

Open Hardware Distribution & Documentation Working Group

The Open Hardware Distribution & Documentation Working Group started in July 2020 and ended in May 2021. The short-term goal of the group was to produce a proof of concept for distributed Open Science Hardware (OScH) manufacturing using the OpenFlexure project as a case study. In the longer term, the working group hoped to help enable sustainable distributed manufacturing in OScH. We hope our experience and insights, as documented in this report, motivate and inform others in future discussions and implementation of an expanded distributed manufacturing landscape for OScH.

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Acknowledgments

Thank you to all working group participants for their valuable contributions to the group and in reviewing this document. We also want to thank the members of the Open Science Hardware community for their helpful comments and advice throughout the process. Authors of this report are bolded on the list below. The members of the working group are:

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Introduction

Open hardware[1] regularly showcases the power of open, distributed design. From emergency response to innovative electronics to complex machines, time and time again geographically distinct communities have come together around a shared set of challenges to iteratively design hardware to meet their collective needs. These open designs continue to improve through collective collaboration, adapting to meet specialized or specific needs.

With notable exceptions, the promise of the distributed manufacturing of hardware has been harder to realize.[2] While designing hardware can largely happen in a virtual space, manufacturing hardware requires components to be procured, assembled, tested, and distributed in the physical world. Once that hardware is created, it often needs to be supported as its user base extends beyond the original creators and community members willing to assemble the hardware from scratch. Manufacturing at scale can require more formal, dedicated infrastructure that often exceeds the capabilities or interest of the original design community. As a result, however large the design communities involved, many of the most successful open hardware projects have been manufactured by a much more concentrated set of entities.

Nonetheless, the ability to manufacture and distribute locally is key to unlocking the full potential of open hardware. Local manufacture and distribution makes it easier for hardware to reach specific markets, and to be customized for local needs. It can also help to bring open hardware beyond its original design community to larger audiences.

1 Open Hardware or Open Source Hardware is one model of technology transfer and development where designs for hardware are shared openly for anyone to freely use, modify, and commercialize. The Open Source Hardware Definition states in part: “The hardware’s source, the design from which it is made, is available in the preferred format for making modifications to it [...] Open source hardware gives people the freedom to control their technology while sharing knowledge and encouraging commerce through the open exchange of designs.”

2 The global response to the COVID crisis vividly illustrated the potential of the distributed manufacture of collaboratively created open designs. Objects such as Personal Protective Equipment (PPE) were refined by global networks and then manufactured and distributed by local (often volunteer) networks. While inspiring, this example is still more the exception than the rule.

This paper documents an attempt to explore sustainable, generalizable ways to build the infrastructure necessary to manufacture and distribute open hardware around the world. It is the result of an Open Hardware Distribution & Documentation Working Group convened by a small group of developers and practitioners to discuss building production infrastructure, using the OpenFlexure Microscope as a case study. For a year extending across 2020 and 2021, the working group discussed ways to refine the microscope from a one-off build that had been replicated by many different builders to hardware that could be manufactured and distributed by partners worldwide.

That process involved exploring the design and documentation for the microscope itself, as well as the commercial, legal, and manufacturing infrastructure that would be necessary to make the hardware available. The initial goal of the working group was to develop and support a network of local manufacturers to make the microscope available in different parts of the world.

A key principle of the exercise was "no unicorns." Based on previous experience, the working group determined early on that it was not reasonable for the success of an open hardware project to rely on a single person or small team to do the combined activities of:

- designing the original hardware prototype,
- refining the prototype into a design manufacturable at a number of scales and in a number of environments,
- creating the commercial and legal infrastructure required to advertise, sell, and distribute the hardware, and
- supporting the hardware once it was in the hands of end-users.

Instead, the working group collaborated to identify and define the different roles that would be involved in a successful distribution effort, and to understand how those roles might relate to each other in an effective, reproducible way. Along the way, the working group detailed a number of factors, considerations, and choices that a project would need to consider before establishing a distributed manufacturing and distribution network. These elements are especially relevant to open science hardware that has been developed in different environments, from the academic lab to community projects or small companies.

This paper documents those findings. It describes the factors that could be considered in creating a sustainable model for open hardware distribution. It also describes different approaches for weighing those factors.

Although it does not provide a single path forward, the working group believes that this paper provides a framework for future discussion.

READ MORE: Open Hardware Distribution & Documentation Working Group: Intro

Goals

The primary goal of the working group's discussion was to map a path for hardware to become widely available even when it is developed outside of a commercial context and where its developers are not primarily interested in manufacturing and distribution (e.g., they are academics or members of community projects). We were especially interested in availability to users who did not have the capacity or interest to build the hardware themselves, as well as end-users outside the original developers' region. This process can be thought of as "commercialization" (in the sense that the hardware becomes widely commercially available) and "productization" (in the sense that the hardware is standardized in a way that allows it to be manufactured and supported at some sort of scale). Financial viability is an important factor in the long-term sustainability of the model. Nonetheless, the goal of the discussion was not to commercialize and productize the hardware in order to maximize the profitability of the distribution model. Instead, the goal was to maximize the availability of the hardware itself in ways aligned to the values articulated by the GOSH Manifesto.[1]

In order to achieve that goal, the working group collaborated to identify the structures, roles, and processes that are required to successfully—and sustainably—distribute hardware at scale. As the Options section illustrates below, once identified, these elements can be organized in a number of different ways.

In addition to these high-level goals, the working group identified a number of more specific goals to help guide the exploration:[2]

- Manufacture in a way that supports the goals of the GOSH Manifesto
- Provide users with a consistent, comparable, high-quality product
- Provide users with high-quality, local, and context-appropriate support, feedback, and maintenance options
- Create sustainable business by ensuring a sufficient amount of work for partners
- Provide skilled opportunities for hardware engineers
- Increase access to open hardware in the regions close to the distributed manufacturers
- Embed environmental and economic sustainability alongside open approaches to development and production
- Seek to include new manufacturers and/or new regions in the future

1 https://openhardware.science/gosh-manifesto/

2 These goals and values were captured in a collaborative document available at https://gosh-community.gitlab.io/open-science-hardware-collective/mkdocs/consolidated_governance_notes/

Open Science Hardware (OScH) Values Considered by the Working Group

OScH is Accessible	Increase access to OScH in the regions close to the distributed manufacturers
OScH Makes Science Better	Provide users with a consistent, comparable, high-quality product and high-quality, context-appropriate support and feedback
OScH is Impactful Tools	Create sustainable business by ensuring a sufficient amount of work for partners
OScH Empowers People	Provide skilled opportunities for hardware engineers
OScH Has No Black Boxes	Provide local technical support and maintenance options
OScH Allows Multiple Futures for Science	Prove that openness combined with environmental and economic sustainability is feasible

READ MORE: Open Hardware Distribution & Documentation Working Group: Values-Based Standards for Manufacturing (pt. 1 and pt. 2)

Elements

The working group started by mapping the various elements required to successfully manufacture and distribute hardware. The goal was not to create a single structure to contain the elements. Instead, this process was designed to identify the elements that would need to be accounted for in any possible approach. Once the working group understood the elements needed for successful distribution, it could move on to explore ways to successfully arrange those elements into a framework.

This section serves as something of an initial checklist for open hardware distribution. Any team hoping to successfully distribute open hardware should have an understanding of how it will provide each of these elements as part of that effort.

Working Prototype

The starting point of the project is a working prototype. This is an admittedly slippery category. The state of the OpenFlexure Microscope provides a good example of what can qualify as a working prototype.

At the start of the exercise, the OpenFlexure Microscope had already been fully developed at the Bath Open INstrumentation Group (BOING) under the guidance of working group members Richard Bowman and Julian Stirling. The hardware design worked and could be assembled by hand in an academic lab or hobbyist workshop. The design was documented and had been reproduced independently across the world. However, a lack of clear specifications for procurement and procedures for monitoring quality made manufacturing difficult without direct support from the original OpenFlexure team. The design had also not been optimized for durability or manufacture in large batches.

Unlike the other elements in this section, the working prototype is not something that will be part of a final distribution mechanism. Instead, the working prototype is the foundation that distributed manufacture is built upon.

Documentation

Documentation must be accessible and complete in a way that allows someone who is not in regular contact with the original design team to be able to understand, build, support, and improve the hardware.

At the beginning of the exercise, the microscope had been fully documented and reproduced independently by a number of people who have built microscopes without any interaction with the designers. However, that documentation was focused on customizability and covered all variations and possible customizations of the microscope design. The documentation also combined assembly instructions with an explanation of the design rationale, which was useful for the initial use case because most reports from independent builders of the microscope mentioned some degree of adaptation or improvisation, usually because of differences in available components or difficulty sourcing specific parts. This first version of the documentation required a base understanding of microscopy to use, and was therefore not appropriate for consistent production of a specific microscope design.

> *Example from the first version of the assembly instructions: "Take M3 screws (8-12mm long), probably cap screws or button screws if you prefer (I like cap screws here so they use the same Allen key as the M4 buttons). Push them into holes A and B. These holes are here to make sure the flange stays in line with the gizmo. It might be good to use dowels later but I am not able to size them? Maybe rivets. Now secure with a nut, or perhaps a nylock nut?"*

In order to make the documentation more useful and accessible for distributed manufacturing, the team decided to split the existing documentation into four resources. Each version of the resource was targeted at a specific audience.

Audience	Document Required
Manufacturing partners (potentially with different technical capabilities)	Assembly and Manufacturing Instructions
End-users trying to figure out how to get the thing working when they take it out of the box	User Manual/Operating Manual
End-users trying to troubleshoot	Design Rationale
People doing more significant repair	Service Manual

The first resource was a set of assembly and manufacturing instructions. It focused on allowing manufacturers to create a single, consistent version of the microscope that could be tested against quality standards, in contrast to the prototype assembly instructions described above.

> *Example assembly and manufacturing instructions: "Get a 2.5mm Allen key, and 5.5mm nut driver ready Take two M3x10mm cap head screws. Push screws through holes A and B. Secure screws finger tight with two M3 nylock nuts using the nut driver and allen key"*

The second resource was an operating manual for end-users. It was designed to help people get the microscope from the box to the lab.

> *Example user manual for end-users entry: "Before powering up the device ensure that the flange and gizmo are held in alignment with two screws, and that their nuts are tight. Tighten loose nuts before use. If screws are missing, do not use the device. See the service manual for realigning the flange."*

The third resource explained the design rationale behind the microscope. This allowed end-users to understand and improve upon the design, as well as troubleshoot less straightforward problems.

> *Example design rationale entry: "The flange is aligned with the gizmo by two screws, that pass through holes A and B. These screws are M3 cap head, so that the same Allen key can be used for the M4 button heads later on. The screws are secured with a nylock nut so they can't work loose, but they don't actually need to apply any compression. Other options considered are dowels and rivets. Doweling would require a redesign of the flange and gizmo to hold the dowels captive and better tolerance to hold the dowels firm. Rivets are a more durable alternative, these have been avoided as they hinder disassembly and repair."*

Finally, the team has started to add a service manual. This manual is geared toward sophisticated users and repair technicians who can benefit from a full understanding of how to fix problems with the hardware.

> *Example service manual entry: "If the flange is misaligned, check there are M3x10 screws passing through holes A and B into the widget, secured with a nylock nut. Without these screws, it's easy for the parts to get misaligned. Vibration can cause these screws to loosen, particularly if the recommended nylock nut is not used."*

As this new list of documentation requirements illustrates, meeting the documentation needs of a product requires multiple (coordinated) documentation formats. This is often a significant change from the project's original, often informal, documentation shared by a small team working to rapidly prototype the hardware.

Product

Once the team had a working prototype, it needed to be transformed into a product. This meant creating a version of the microscope that could be assembled in batches larger than those created in the lab. It also required focus on the reliability and robustness of the devices, for example enclosing stray cables and securing parts more firmly.

The journey from product to prototype will be specific for each piece of hardware. For some hardware it may involve only small changes to the original prototype. For other pieces of hardware it may require a fundamental redesign. In all cases the goal will be to bring the hardware from something that "works in the lab" to something that can be reliably manufactured, can work reliably for months without maintenance or adjustment, and can be supported sustainably. In practice this means that users of the hardware rarely need to reach out to the manufacturers for support, and that in turn the manufacturers rarely need to reach out to the original design team in order to understand the hardware.

READ MORE: Open Hardware Distribution & Documentation Working Group: Same brand, different products

READ MORE: Open Hardware Distribution & Documentation Working Group: Getting better by tracing failures

Manufacturing Capacity

Creating and distributing hardware—especially across national borders—is very different from creating and distributing software. Once software is written and posted online, perfect copies are available to anyone at no marginal cost. Every copy is the same as the original. There are no upfront costs to make an additional copy of the software. There is no customs regime to navigate or distribution networks to assemble. If an end-user's version of the software is corrupted, it can be replaced for free.

None of this is true for hardware. The practices of the entity manufacturing any given piece of hardware will have a significant impact on how closely that individual copy matches the original designs. Manufacturing the hardware requires upfront costs including storage space, materials, personnel, and equipment. At scale, even the more common electronic assembly and computer-controlled mechanical production can require hundreds of thousands of dollars' worth of investment. Importing parts and exporting final goods across international borders can require navigating a complex set of international customs and tax regimes. If a piece of hardware breaks, the entire distribution process needs to be reactivated to replace or repair it.

As a result, manufacturing and distributing hardware at scale requires more permanent infrastructure than the equivalent activity in software. This infrastructure does not need to come in the form of a single company, or even a single network of companies. As described below, there are many potential ways to create and support this capacity. Nonetheless, manufacturing and distributing open hardware at scale does require it to exist in some form. This capacity will also be more expensive to maintain than the capacity for an equivalently sized open software project.

READ MORE: Open Hardware Distribution & Documentation Working Group: Building for your audience

Promotional & Marketing Capacity

Hardware does not automatically find its user community. Successful efforts to manufacture open hardware focus on an actual user. Fostering these users requires some level of dedicated promotional and marketing capacity.

As with manufacturing capacity, this capacity does not need to be centralized in a single entity. It can be distributed in any number of ways. However it is configured, it is a critical component of successful open hardware manufacturing and distribution and anecdotally is a challenge for many small manufacturers and distributors of open hardware.

In some cases if the developer, manufacturer, and distributor are deeply embedded within a small and tightly knit scientific community and marketing a specific and niche product for that community, high penetration of awareness can occur by word of mouth as “everyone knows each other” or at least attends the same specific meetings and is on the same mailing lists and social media channels. However, for generic scientific hardware like a microscope, end-users could come from many experimental disciplines and many areas of the world. This creates opportunities for the hardware to create impact in a number of different fields, but it also makes it challenging to achieve awareness in a significant proportion of your potential market.

Post-Distribution Support

Hardware that end-users cannot understand—or fix when it breaks—is of little use to anyone. Once the hardware is distributed, it must also be supported. This support can include troubleshooting help, replacement parts, and connections with a larger community of users or even with local service engineers.

Assumptions

After identifying the key elements of a successful distribution project, the working group began to explore various options for structuring those elements. That process was shaped by a number of assumptions about the nature of a successful distribution project.

Emergent Order is Not Enough

While decentralized, flat, ad hoc networks can be incredibly powerful in some contexts, the working group quickly concluded that a sustainable distribution project could not simply rely on emergent order to succeed. Instead, a successful project requires some amount of intentionally created infrastructure that allows different stakeholders to coordinate.[1]

This is a direct result of a "no unicorns" approach. When one person—or one small group—is responsible for an entire project, that person (or small group) can rely on informal structures to coordinate activities. However, if a wider range of stakeholders are responsible for various tasks, that larger group will need some type of formal system to coordinate, discuss, and prioritize activities.

Infrastructure Needs to Create Incentives for All Stakeholders

A successful distribution project requires collaboration with a wide range of stakeholders coming from a number of perspectives, each of which is participating for its own reasons. The need for a specific role—a manufacturing partner, or post-distribution support infrastructure—will not automatically create a stakeholder willing to fill that role. Instead, those stakeholders need to be induced to join the effort. That requires infrastructure and systems that give all necessary stakeholders an incentive to participate.

1 For more on the importance of formal structure in informal groups, see Jo Freeman's *The Tyranny of Structurelessness*, https://www.jofreeman.com/joreen/tyranny.htm

While well understood by the OpenFlexure team, this perspective can be hard for the originators of open hardware projects to recognize. The creators of open hardware projects are passionate about the hardware and have secured the time and resources needed to create a working lab prototype. The original team is often sustained in large part by the excitement of seeing the hardware emerging out in the world. Although many stakeholders will share this excitement, the excitement alone may not be enough to incentivize them to step into the role expected of them by the larger project, or to take on the associated financial risks. As such, it is important to design infrastructure that gives all participants the motivation they need to participate. Those incentives can take many forms, including the ability to generate a profit, build a brand, expand a market, add expertise, and/or develop networks.

Infrastructure Requires Resources

Open hardware manufacture and distribution requires resources. Like the need for infrastructure itself, the need for resources that support the infrastructure requires open hardware to be more intentional in developing distribution strategies than open source software.[2] Failing to account for this requirement is likely to result in the failure of the effort.

These resources can come in many forms from many sources, including sale of the hardware itself, revenue from training related to the hardware, and initial capital (such as through support from a private foundation, crowdsourcing campaign, government research award, private investor, etc.).

Trust (in the Design, in the Manufacturer, in the Community) is Currency

Open hardware contains value that can be leveraged to create the resources required for distribution. One of the most important reservoirs of value that an open hardware community can have is trust. Compared to software, hardware can be expensive to acquire, calibrate, and maintain. That makes the stakes of getting things right the first time high for hardware. Trust—in the design, in the manufacturer, in the distributor, in the community—is what gives people confidence to incorporate the hardware into their activities.

Trust helps give end-users confidence that any given piece of hardware will work. That trust starts with a trust in a design, understanding that it has been tested and optimized to achieve the intended goal. An important effect of openness is enhancing that trust because the full design can be inspected and reviewed. It extends to trust in the manufacturer, recognizing that in many ways a trustworthy design is only as useful as the entity that takes the design and turns it into a specific piece of hardware. Finally, trust in a community gives users a way to get help, find improvements, and continue to use the hardware in the most effective way possible.

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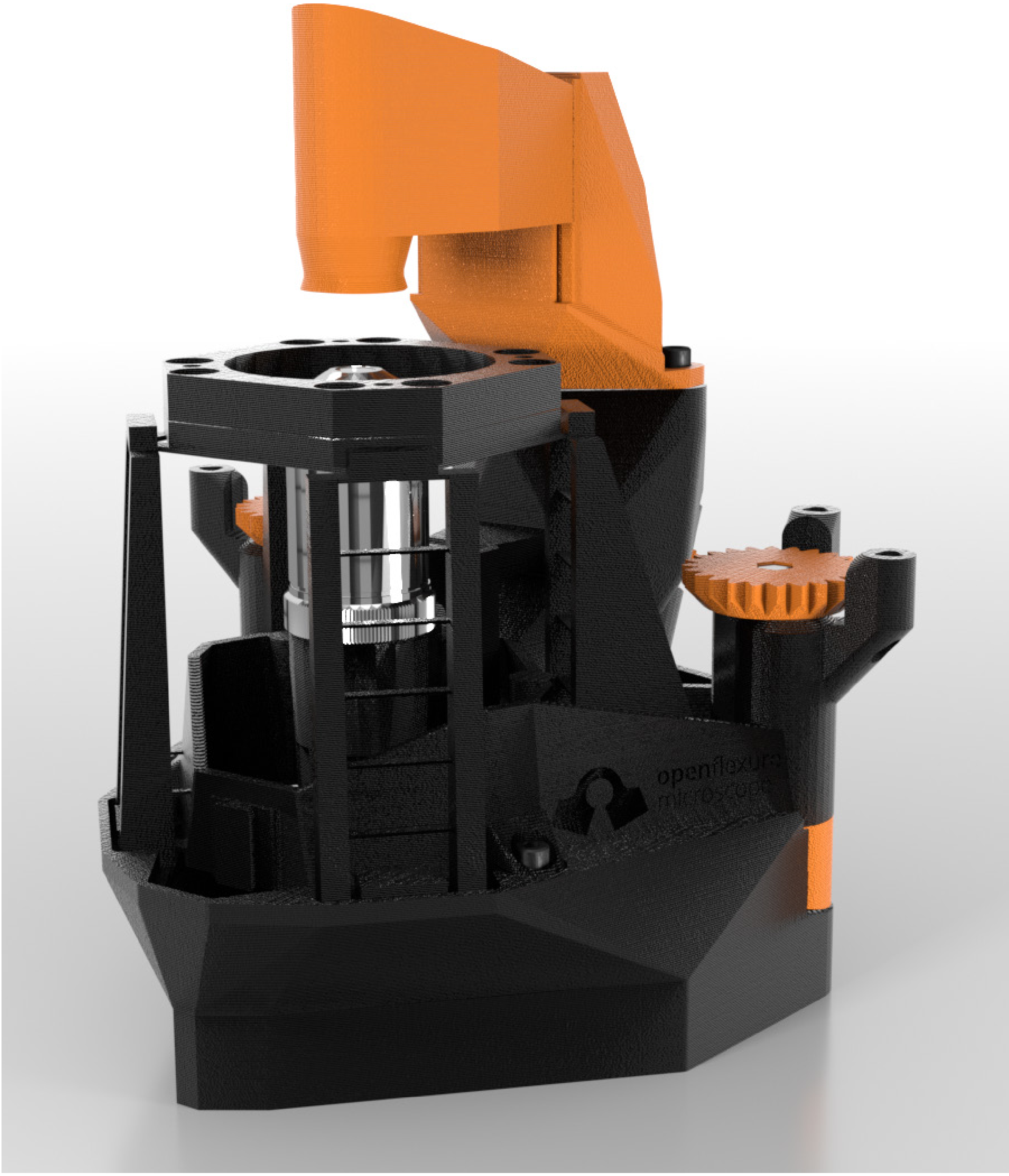
2 Experience has shown that most truly successful and sustainable open software projects rely on formal structures and dedicated resources as well.

Success Likely Requires Upfront Costs

Unlike software, hardware infrastructure cannot be built on an on-demand basis. Productization, supply chains, manufacturing capacity, and marketing all involve non-trivial commitments before the first pieces are manufactured and delivered. Unlike software, the first versions of hardware cannot always be patched until they are fully stable. Instead, the first versions of hardware need to be stable before they are distributed.

That means that a successful distribution initiative will have a plan to pay those costs as part of the launch of the project. Depending on the long-term distribution model, it may or may not make sense to think of these startup costs as being distinct from the ongoing costs of manufacturing and distributing the hardware.



A render of the OpenFlexure Microscope

Questions

Reviewing the goals, elements, and assumptions involved in successfully distributing open hardware raised a number of questions. Some of these questions can have fairly straightforward answers. Others go directly to the core of the organizational structure. As with the Elements section, a successful effort to distribute open hardware will have considered these questions before distribution begins.

Who Does the Marketing Work?

A successful distribution network may include a number of different stakeholders—original designers, manufacturers, distributors, community members. Some type of marketing will be required to bring the hardware to new audiences and help users understand why the hardware could be useful to them. Which stakeholders are responsible for this work? Where do the resources come from, and what kind of autonomy do they have to shape the message and how it is targeted?

Where Does the Brand Value Attach?

Over time, a successful open hardware project will build a brand that users trust and rely on. What is that brand centered on? Is it the hardware itself, independent of who manufactures it? A company or organization that becomes particularly effective at manufacturing it? A certifying body that verifies that all of the versions of the hardware meet certain standards? This is a question that can have multiple answers. However, it cannot have unlimited answers. At some point, stakeholders will need to decide how to represent themselves to end-users. The Options section below explores some of the different possible configurations.

Who Guarantees Quality?

Closely related to branding questions, the party that acts as the ultimate guarantor of quality can be critical for open hardware. Open hardware is open. Anyone can take the plans and build their own version. Not all of those versions will meet minimum quality standards, or even work. In light of that, where do end-users look for a guarantee of quality? The name of the hardware itself? A trusted manufacturer? Some sort of producer certification?

How is Control Distributed Across Stakeholders?

The existence of infrastructure for hardware distribution raises questions about the control of that infrastructure. Which stakeholders should have control over which elements of the infrastructure? How are disputes resolved? How can the structure be altered?

READ MORE: Open Hardware Distribution & Documentation Working Group: Contracts and Agreements

What Incentives Exist to Contribute Back to the Community?

Successful open hardware projects evolve and improve over time. These additions can come from a wide range of actors within the hardware's ecosystem, for example the original developers, independent developer teams, and end-users or manufacturers. The nature of the additions can be heavily influenced by the structure of the distribution network. How can this network structure incentivise ongoing contributions from an optimal number of participants?

What Qualifies As Adequate Documentation?

The type of documentation required by the original designers of hardware to assemble it themselves is very different from the type of documentation required for distributed manufacturing at scale. Documentation can range from simple schematics to detailed assembly instructions and testing protocols. A distribution project should assess the type of documentation its intended structure requires, including assembly instructions, user manuals, and troubleshooting guides. If ongoing maintenance and improvement of the design will be taken on by someone other than the original designers, documentation of the design rationale, software toolchain, and planned or partially implemented features may also be needed.

What Level of Activation Energy is Required to Launch the Initiative?

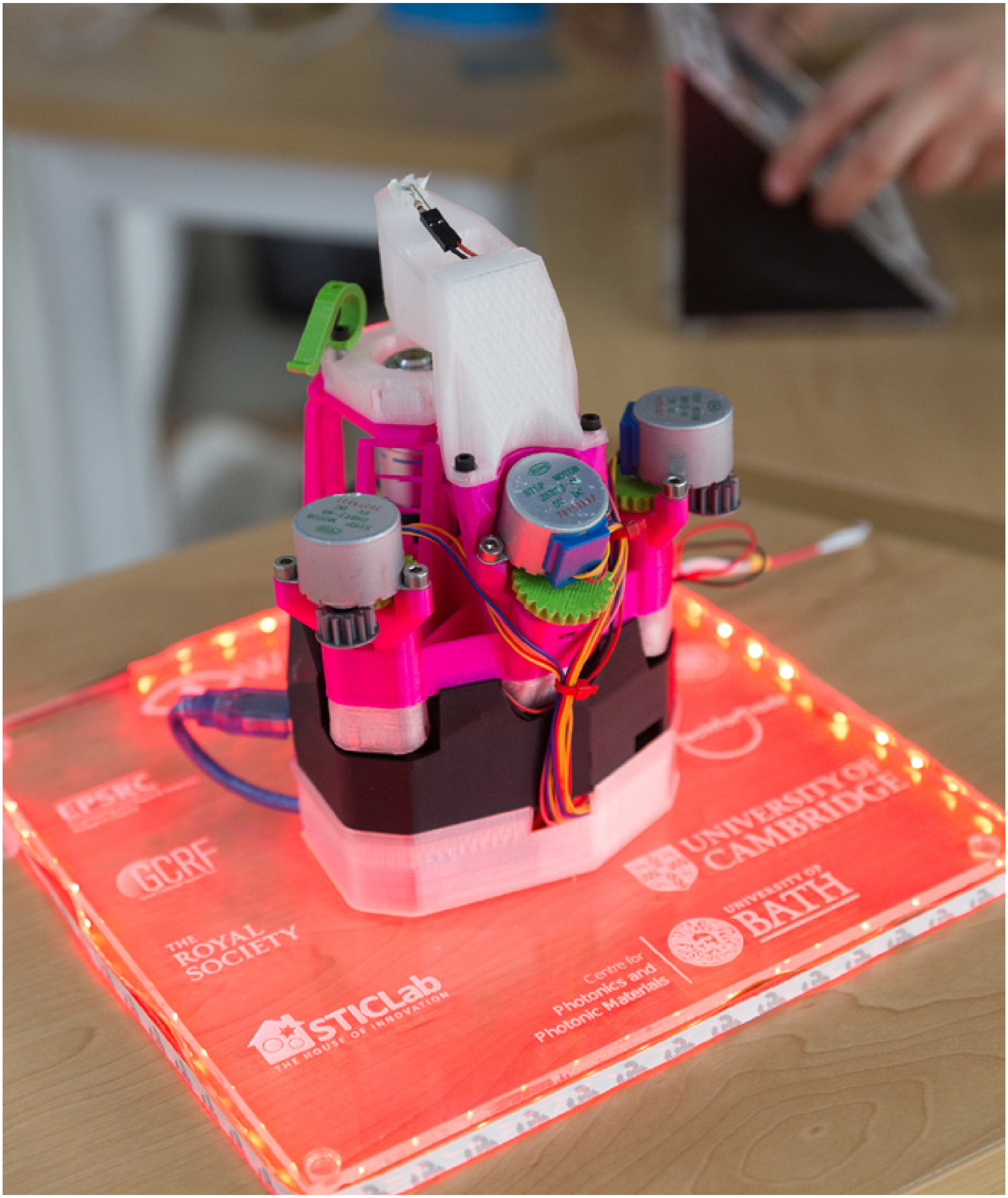
As noted a number of times in this report, distributed manufacturing of open hardware does not simply happen. After determining the distribution strategy for a given piece of hardware, stakeholders should take the time to discuss if they have the ability to execute that strategy. If the minimum viable strategy for distributing hardware requires the full-time commitment of 5 people for 5 months and there are not 5 people willing to take on that role, it may be better to recognize that fact than to try to achieve the project's goals with inadequate support. Similarly, if launching a project will take at least $20,000 and the stakeholders have only $5,000, it is unlikely that the project will be successful.

Who Provides Aftermarket Support?

It is easy to view the moment a user receives hardware as the end-point of the distribution process. In reality, successfully distributed hardware is successfully supported hardware. How is the hardware supported once it is distributed, and which stakeholders are responsible for maintaining that support? What is the relationship between support, manufacturing, and design?

How are Stakeholders Compensated?

Stakeholder compensation is key to the long- (and even short-) term success of any hardware distribution initiative. Compensation does not need to be financial, and does not need to come from the same source for everyone. Nonetheless, an open hardware distribution project that does not understand how people will be compensated is unlikely to retain those stakeholders for very long.



The OpenFlexure Microscope on display

Image: University of Bath, CC BY-SA 4.0

Operational & Governance Structures

While there are many viable ways that an open hardware project can structure its distributed manufacturing plan, ultimately it will have to settle on a single model. That model will need to address the questions discussed in this report and accommodate the specific needs of the stakeholders involved. One of the key decisions that the project will need to make has to do with centralization—how much operational responsibility and decision-making authority will be centralized, and where?

One way to think about questions of centralization is through the lens of the project's brand. The brand is the public face of the project and the artifact that embodies the trust foundational to the success of open hardware. Another is to consider the administrative and legal structures that might formalize stakeholder relationships.

In addition to branding structures, this section also explores two other possibilities that can impact the organizational structure of the project. The first, Commercialization-as-a-Service, describes an entity that could assist in the journey from project to product. The ultimate structure of that service could significantly impact how the project stakeholder relationship is structured. The second, a cooperative approach to ownership, is an approach to organizing the legal control of a legal entity that controls branding.

Lastly, it is also possible for a project to simply put information about hardware out in the world in the hopes that others will decide to manufacture, distribute, and support it. Experience suggests that this type of "post and hope" strategy is unlikely to foster a robust distribution network.

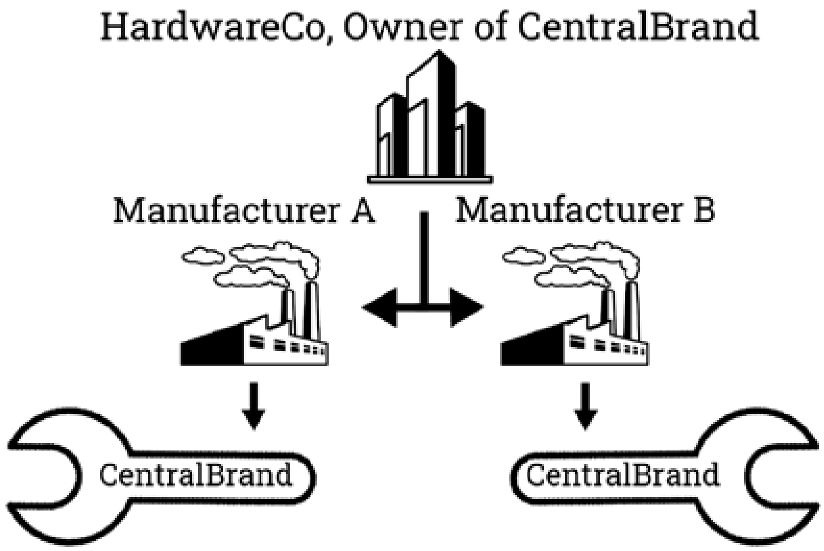
Brand Governance

An open hardware project's brand is how it is known to the community. It can be used to highlight all of the stakeholders involved in its creation or to consolidate all of those stakeholders under a single name. Thinking about how the project's brand is represented to the public—and the different stakeholders' ability to control that brand—can be a helpful way to think about the stakeholder relationships more broadly.

Most of the structures described in this section rely on control of a brand or trademark in order to create a set of reciprocal obligations among stakeholders. If a central entity has legal control over a brand name or trademark, it can license that brand name or trademark to other stakeholders. That license can require manufacturing partners to meet minimum production standards, use tested versions of designs, and contribute improvements back to the collective.

The branding options described below largely start with the assumption that the central legal entity has formal control over the trademarks and other branding related to the project. It is possible to create a structure where the original designers have formal legal control over the trademarks and branding, and then license those rights to the primary legal entity. This kind of structure should only be considered with a full appreciation of the impact that federated control might have on the project's ability to represent itself consistently to users.

SINGLE PUBLIC BRAND ("CENTRALBRAND")



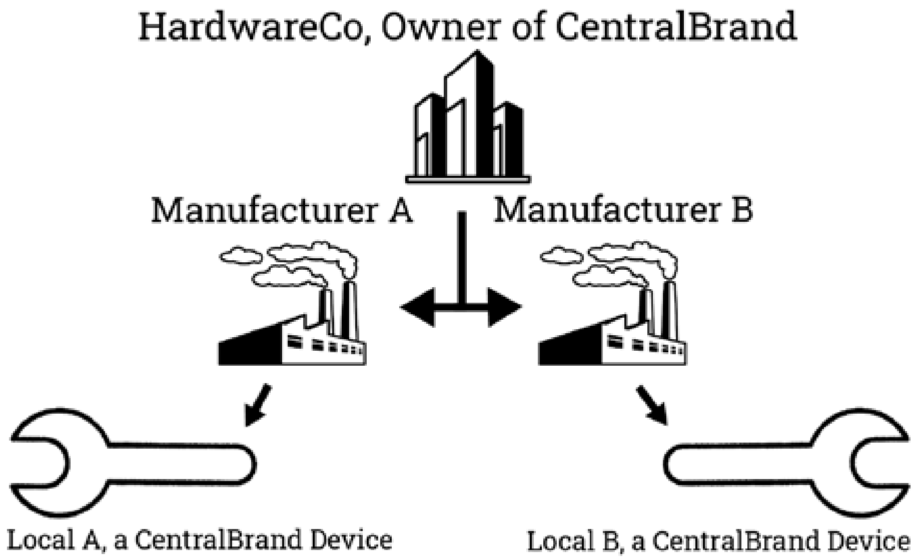
Stakeholders can decide to create a single public brand controlled by a central entity around the hardware project (the "CentralBrand"). In the context of the OpenFlexure project, that would mean distributing the OpenFlexure Microscope as the OpenFlexure Microscope no matter who manufactured any given microscope. With the OpenFlexure Microscope brand in the forefront, local manufacturing partners become part of a supply chain that is obscure—if not invisible—to purchasers, although they may be very visible to end-users if they are also offering local or specialized support services. This is the model that is used by most commercial hardware, where the supply chains and manufacturing networks are hidden behind the primary brand name of the hardware.

This approach requires all of the hardware to be overseen by a central entity that controls the brand name. That makes it easier to standardize quality, and to coordinate marketing, sales, and distribution strategies. It also makes it easy to track versioning and to integrate improvements across the distribution channel.

Those efficiencies do come at a cost. Because most of the brand benefits flow to the central organization, it is likely that the central organization will also be responsible for most of the marketing and market-building. Distribution partners are less likely to be incentivized to allocate resources to building a brand that they do not share control over. Similarly, as hidden participants, local manufacturing partners will be less invested in the hardware project's development and success. That makes them less likely to contribute back to the project. Global standardization of the product also removes the opportunity for local producers to tailor products to their context. Under this model, many of the stakeholders outside of the central organization become something closer to contractors. However, as discussed below in the Cooperative section, the structure of the central entity can be used to re-engage those local manufacturing partners more directly in its success.

READ MORE: Open Hardware Distribution & Documentation Working Group: A centralized hub to support decentralized distribution

DUAL BRANDING ("LOCALBRAND, A CENTRALBRAND DEVICE")



An alternative approach would be to allow local manufacturers and distributors to use their own brands (the "LocalBrand"), while still allowing them to link it to a global brand controlled by a central entity (the "CentralBrand".) In the context of the OpenFlexure Microscope, that could mean that a local manufacturing partner could make and market their version of the microscope as "LocalBrand, an OpenFlexure Microscope."

This dual branding model allows local manufacturers to build their own market identities with their own brands and branding, potentially with modifications for particular markets. At the same time, all of the locally produced versions of the hardware could be linked to a global trusted brand maintained by the central organization. Because the central organization would control the global brand, local manufacturers would have to enter into license agreements with the central organization in order to use it. The central organization could condition the use of the brand on local manufacturers meeting various quality or other standards.

Users would understand this dual branding as meaning that the central organization is deeply involved in the creation and quality of the hardware. At the same time, because each local manufacturer creates their own branded version, users would also understand that local versions may have modifications not found on versions produced elsewhere.

This approach allows the central organization to build an overarching set of feature and quality expectations in connection to the hardware by retaining a trademark to license to other stakeholders. The approach also frees local manufacturing partners to meet local conditions and provides those partners with an incentive to innovate in order to differentiate their version of the hardware from others. This structure continues to support relatively high levels of coordination while giving production partners the ability to deviate from a single set of designs and to retain some of the value from building their own market.

The importance of the CentralBrand as a unifying element will likely mean that the central organization will retain a significant portion of the burden of building the market for the hardware. It also requires the central organization to allocate resources to tracking specific local versions in order to make sure that the local versions continue to meet the standards of the global organization. A particularly popular local version of the hardware could also destabilize the balance inherent to this structure by making the LocalBrand more prominent (and therefore more important) than the CentralBrand.

QUALITY MARK

As previously mentioned, trust is essential when manufacturing and selling hardware. However, in fully distributed manufacturing models which do not operate either the single public brand or dual branding model, each open hardware project and manufacturer needs to independently build trust with its end-users. One possible way to confer trust to an open hardware product would be by means of a quality mark, similar to the BSI Kitemark or Underwriters Laboratories service mark. Such a mark would certify that a) the open project itself had performed testing to show that devices—if built with specific procedures—meet their listed specifications, and b) that manufacturers are producing the device in line with these published procedures. How such a certification scheme would verify and enforce such a mark is still an open question outside the scope of this document.

In this model the central entity would act as a steward for the quality mark, setting the standards the mark requires and enforcing its use. While a local manufacturer could feature the mark, that local manufacturer's branding of the hardware would be independent from the central entity.

Commercialization-as-a-Service

Open hardware is often developed in research labs by teams firmly grounded in academia, NGOs, or community projects. While it is possible that some of those team members also have an interest in building commercial products, manufacturing, and support networks, the "no unicorns" principle suggests that a project should not have to rely on these overlapping interests in order to establish local distribution networks.

As a result, it could be helpful to create an entity that focuses on Commercialization-as-a-Service (CaaS) for open hardware. This entity could be built around evaluating the potential user base for lab-built hardware, transforming promising candidates from lab prototypes to products, and then building the manufacturing, distribution, and support networks required to bring the hardware to the users who can benefit from it. While these types of business- and network-building skills often overlap, people with them may not also gravitate toward academic research environments or community-based open science hardware projects.

Such an entity could be evaluated on how many pieces of open hardware it brings to market and distributes directly, or even how many pieces of open hardware it refines to a point where others recognize the market and enter themselves (either with the plans created by the entity or by creating a new approach). A properly resourced version of this entity could efficiently work with a number of pieces of hardware simultaneously, developing networks and expertise required to bring open hardware to market more broadly. The entity could also consider different ways to work with the original creators in order to mitigate concerns that working with such a service would eliminate the original team's control and relationship with the hardware.

Cooperative

Although this section has described a number of relationships between a central organization and the broader set of stakeholders connected to the hardware, that central organization does not need to be fully distinct from the stakeholder community. The central organization is the entity that holds responsibility for the tasks that must occur in order for the hardware to be successfully distributed. It can be cooperatively managed and controlled by a wide range of stakeholders.

One way to enable this control is to structure the central organization as a cooperative. That cooperative organization can be made up of many of the stakeholders involved in distribution, allowing the stakeholders to share in the decision-making, responsibilities, and successes of the organization.

A cooperative organizational structure does not eliminate the need for an entity that takes responsibility for the obligations assigned to the role of the central organization. Instead, the primary benefit of the cooperative organizational structure is that it gives a way for disparate stakeholders to be directly involved in the decisions made by the central organization. Cooperative organizations can be structured in a number of different ways, including ways that give all shareholders equal decision-making power and access to benefits of the organization.

The egalitarian nature of cooperative organizations makes it especially important to clearly define the criteria for becoming a member. Each member of the cooperative shares in the rights and responsibilities of the organization, so each member should meet a minimum threshold of commitment before joining. That commitment can be measured in any number of ways, including financial, operational capacity, or otherwise.

READ MORE: Open Hardware Distribution & Documentation Working Group: Pyramids versus circles — the need for more cooperative/collaborative business models for OScH

Conclusion

A working prototype, no matter how innovative and open, does not automatically transform itself into a widely accessible piece of hardware. The prototype-to-product pipeline involves refining the hardware itself, as well as assembling the infrastructure required to bring that hardware to end-users. This rewarding process requires intentionality on the part of the stakeholders connected to the hardware, as well as the balancing of various options for reaching the goal.

After considering all of these factors, the Distributed Manufacturing Working Group concluded that it was not the optimal group to support the full availability of the OpenFlexure Microscope, given the different priorities, capacities, and approaches of the members. A manufacturing sub-group is now continuing to test distributed manufacturing approaches with their own companies and organizations.

The working group produced this framework for understanding the processes and types of questions and decisions involved in moving toward larger-scale distribution. The OpenFlexure team will continue to make use of this framework as it moves toward the goal of wider-scale distribution and we hope this will be a resource for future groups interested in doing distributed open hardware manufacturing.

Appendix

The working group documented its progress in a series of blog posts, some of which are referenced in the appropriate sections of this report. The full list of posts is below:

1. Open Hardware Distribution & Documentation Working Group: Intro
2. Values-based standards for manufacturing (part 1)
3. Values-based standards for manufacturing (part 2)
4. Defining Priorities
5. Interlude — Adjusting the Compass
6. Introduction to Documentation and Quality Assurance Frameworks
7. Same brand, different products
8. Building for your audience
9. Getting better by tracing failures
10. The importance of a name
11. Creating a network
12. A centralized hub to support decentralized distribution
13. Governing a central organization
14. Pyramids versus circles — the need for more cooperative/collaborative business models for OScH
15. Contracts and Agreements
16. In Summary: Closing the open hardware distribution and documentation working group

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