Shenzhen and the Republic of Tinkerers: Open Source Hardware (OSHW) as Tools of Global Governance in the Hackerspaces and DIYbio labs

In memory of David Conz, a maker, brewer and friend of the Tenth or Eleventh Muse of tinkering and invention:

How can my muse want subject to invent,
While thou dost breathe, that pour'st into my verse
Thine own sweet argument, too excellent
For every vulgar paper to rehearse?
O! give thy self the thanks, if aught in me
Worthy perusal stand against thy sight;
For who's so dumb that cannot write to thee,
When thou thy self dost give invention light?
Be thou the tenth Muse, ten times more in worth
Than those old nine which rhymers invocate;
And he that calls on thee, let him bring forth
Eternal numbers to outlive long date.
If my slight muse do please these curious days,
The pain be mine, but thine shall be the praise.

Shakespeare's Sonnet 38[1]

Abstract

From Do-It-Yourself (DIY) radiation monitoring kits in Japan to attempts to democratize thermocycling and microscopy in India, Indonesia and Nepal, and various farm and food hacking projects around aqua- and hydroponics in Shanghai and Singapore, we can follow a similar pattern of global collaborations over open source hardware (OSHW). The OSHW creates conditions for politics to converge with design on a global scale, where tinkering, making and material iterations enable collaborative micro-decisions and micropolitics (Deleuze and Guattari 1987). This self-organization over open source tools defines a type of a global "public sphere", which is "recursive" and "iterative" (Kelty 2008), but also introduces political deliberation based on material, rather than purely discursive practices (Ratto 2011). This convergence between politics and design forces us to rethink our traditional views of governance based on the degradation of makers (demiurgoi) as political actors in Plato's Republic. The blueprint of our governance ideals of separation of powers and various forms of "trias politica" degraded making and production as political activities. Politics since Plato's Republic is opposed to making and designing and it is defined as a contemplative, cognitive and discursive achievement based on the right insight into the true nature of our soul and society. The present network of hackerspaces and DIYbio labs as a utopian "republic of tinkerers" explores an alternative form of governance. It is closer to a later dialogue, Timaios, where Plato introduced a complex agency of the "maker of the

[1] http://www.shakespeares-sonnets.com/sonnet/38

universe" (demiurg), who governs while designing and whose actions are discussed in both, political and ontological terms. The OSHW prototypes introduce tinkering as a way of deliberating upon common future and global issues, where consensus is enabled through testing tools. These prototypes define citizens as not only voters delegating power, but also makers and regulators, as a "public of demiurgoi". With this preliminary genealogy of tinkering and making we would like to propose an alternative view of the hackerspace governance as an experimental model of policy of prototypes, where OSHW enables iterative, collaborative and parallel work on both design and politics.

Introduction

We do not need to visit NASA or travel to Mars to experience future community resilient to extreme conditions. In 2012, a group of hackers, artists, scientists, and farmers set up a unique experimental community around the Merapi volcano in central Java by connecting hacked satellite data, bioreactor working with hay waste and an aquaponic system for fish and vegetables production. The Micro/Macronation project[2] by House of Natural Fiber (HONF- Yogyakarta New Media Art Laboratory)[3] in Yogyakarta, Indonesia, is testing a model for sustainable, future communities living around the volcano. A group of artists, scientists and designers in cooperation with local community leaders connected custom made ethanol reactor, which ferments hay waste, with an aquaponic system designed for a farm, while intensively gathering data on this experiment. They even "hacked" the environmental data from an Indonesian government satellite to define a precedence for open government data projects in the region. They plan to combine the data from the satellite with data gathered from these two experimental villages to define a future scenario for Indonesia, which they hope to present in the parliament. This is just one story describing the emergent forms of hackerspace governance, which supports communities through prototypes by using open source hardware and open design approaches.

The present hackerspaces and maker communities, but also (Do-It-Yourself) DIYbio labs and citizen science movements around the world offer unique opportunities for the Global South in terms of grassroots innovation and scientific research. Laboratory equipment based on Open Source Hardware (OSHW) enables education and research in places with missing infrastructure, but it also supports open and citizen science projects around the world. In terms of (geo)politics, it brings together the interests of the Global south with the interests of tinkerers, makers and science enthusiasts supporting open science and Do-It-Yourself biology (DIYbio) movements, who believe in the importance of democratization of R&D. This emergent governance model behind such geek diplomacy is an antidote to the corporate geopolitical experiments, such as "Stop Online Piracy Act" (SOPA) or the current "Trans-Pacific Partnership" (TPP), which are trying to centralize and cease the power over innovation (Carrier 2013).

The alternative R&D structure around hackerspaces is creating its own network of sharing knowledge, which is independent on the educational, research, government, but also corporate institutions (Kera 2012). It is globally connected through a shared interest in open

[2] The project is documented here: http://www.natural-fiber.com/index.php?option=com_content&view=category&layout=blog&id=63&Itemid=65
[3] HONF website: http://www.natural-fiber.com/

design and open source technologies, which are participatory, inclusive and low cost. This global infrastructure uses tinkering, hacking and collaboration to support the ideals of citizen and open science, but also open source technologies (open source and free software, open source hardware platforms, such as Arduino, custom made circuit boards, digital fabrication). The knowledge is acquired and shared through wikis, instructional videos on YouTube, services, such as Instructibles[4], where anyone can upload and follow a DIY project. The projects are often financed by members themselves, local communities, ad hoc grants and crowdsourcing campaigns.

Karkhana Collective in Nepal[5], LifePatch (Citizen Initiative in Art, Science and Technology)[6] and the House of Natural Fiber (HONF- Yogyakarta New Media Art Laboratory) in Indonesia, Manila Biopunk Movement in Philippines[7], but also Shanghai[8] and Shenzhen hackerspaces[9], Tokyo hackerspace[10], or Sustainable Living Lab in Singapore[11], are some of the organizations, which form this alternative R&D infrastructure in Asia. Globally they are connected to the hackerspace network[12], but also to the DIYbio movement[13], and to a small, but very active network for open biology called Hackteria[14]. The democratic, but also creative appropriations of instructions, science protocols and open source technologies in these networks enable a unique cooperation between universities, art centers, and various local communities. Their projects defy the common stereotypes and divisions between the developed and developing world, between science and society, experts and amateurs, science and indigenous knowledge.

These informal research networks support an original "geek diplomacy" and cooperation based on shared interest in prototypes, which disrupt the innovation and "adoption cycle" described by Everett Rogers (1983). Their prototypes do not follow the common trajectory from the science labs to the design and engineering studios, manufacturing facilities, sales departments, from where we can follow the adoption cycle in a given society and the slow diffusion in the Global South. The prototypes and kits created in the hackerspaces and open biology labs around the world decentralize and open the process of development, but also testing, modifying, and the adoption to a truly global community of hackers, makers, and enthusiasts with various needs, concerns, and goals. This opens a possibility for plural policies and adoptions to occur, where specific communities in different regions can shape the design to serve their own needs and to decide under which conditions they will accept them. Through these open source tools and prototypes communities can to modify, adjust, and reflect upon the given technologies.

Open Science and Open Technology Networks in Asia: Yogyakarta

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[4] http://www.instructables.com/
[5] http://www.karkhana.asia/
[6] http://lifepatch.org/
[7] http://www.manilabiopunk.org/
[8] [Xinchejian] Hackerspace in Shanghai: http://xinchejian.com/
[9] Chaihuo hackerspace in Shenzhen: http://www.chaihuo.org/blog/
[10] http://www.tokyohackerspace.org/
[11] http://www.sl2square.org/
[12] http://hackerspaces.org/
[13] http://diybio.org/
[14] http://hackteria.org/

As an example, we can use the Hackteria DIY webcam microscope and its stage kits[15], which describe the complex networks around open biology, the forms of knowledge transfer and alternative R&D cycle. While the original, 2009 prototype was based on a common Youtube and web description of how to turn webcam into a microscope, it quickly developed into a PS3eye webcam version, because it was capable of working with low light intensity. These Playstation webcams were precise enough to be useful for the needs of the students from UGM Microbiology Lab – Faculty of Agriculture, where Marc Dusseiller from Hackteria was organizing workshops on hacking webcams (Siagian 2012). One critical component was always the stage, which makes the microscope stable, manageable and functional. The various educational, artistic and research projects in Indonesia were using the original prototype with many improvisations, and only in 2012 one of the Hackteria members, Urs Gaudenz, in cooperation with Luzern Fablab, designed the first laser-cutted microscopy stage. He sent two of these kits to Indonesia to the UGM Microbiology Lab and to their affiliated, nonprofit organization of citizen scientists, Lifepatch, who after some experiments created clones and improved the design of the stage in 2013.

Since 2012 Lifepatch was using microscopy for open science workshops with disadvantaged children in Yogyakarta and they needed the stage to simplify the whole kit. Since it was expensive to ship the kits from Switzerland, a Lifepatch member copied the original laser-cutted stage from Fablab Luzern and crafted it manually into an artisan, hand-made object[16], before finding a laser cutter to make an improved clone of the stage, which is offered in the present as a kit. What is important to notice in this hardware "dialogue" between Switzerland and Indonesia, is the connection that was created between traditional (glassmaking) crafts and a Fablab style, digital fabrication object. This dialogue between traditional crafts and digital mass production would be impossible in the common R&D cycle. This example shows how the OSHW models of collaboration enable adaptation and unique interactions between old and new technologies and materials, which ultimately supports building a local research infrastructure and capabilities.

The artisan microscopy stage copied the digitally fabricated, fablab prototype, by paradoxically using acrylic leftover material form laser cutting, which was lying around at the Lifepatch studio [17]. This unique, artisan stage for a hacked webcam was built by Radix Nugroho from Otakatik Creative Workshop, which upcycles glass and collaborates with Lifepatch and other citizen science organization. This first Lifepatch and Otatik kit for a microscopy stage was "cloned" manually, but the later (laser cutted) versions followed and improved the Hackteria's stage design. In a short period of two months, Lifepatch members designed their own Indonesian clone and created a microscopy stage kit (Siagian 2013). They also explored the possibilities of using recycled local materials in order to make it cheaper, but also enhance its value, so it becomes an aesthetic product and an artwork.

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[15] DIY microscopy resources: http://hackteria.org/?cat=15

[16] DIY microscopy stage kit – Indonesian clone: http://hackteria.org/?p=2082

[17] Documentation of the whole process in photos: https://www.facebook.com/photo.php?fbid=299885063470577&set=a.182960105163074.37706.144301485695603&type=1&relevant_count=1, also https://www.facebook.com/media/set/?set=a.549545511747116.131034.284578538243816&type=1 and http://www.flickr.com/photos/92698778@N04/8447886916/in/photostream/

OSHW prototypes, kits and clones often form such "hardware dialogues" and improvisations between various countries, in our case between Indonesia, India and Switzerland, where the majority of Hackteria members are based. In 2012 the Indonesian members cloned not only the microscopy kit, but also the simplified microcontroller on a USB stick, called GNUSbuino, which is used among other things for controlling a diode on a turbidity sensor to gather simple data for water analysis. This Swiss microcontroller was introduced in a workshop in Yogyakarta in January 2013 and then transformed by the Indonesians geeks into a cheaper, BabyGnusbuino Tropical DIL version v0.3, which uses electronic parts available in Yogyakarta[18]. The microscope stage as well as the microcontroller were used at a workshop during Shanghai Maker Fair in October 2013, where they attracted the attention of Eric Pan, a CEO of Seeed Studio[19] in Shenzhen, an important online open hardware marketplace, which supports hardware developers around the world. The Lifepatch members in cooperation with Hackteria and Seeed Studio are now trying to introduce a new line of DIYbio kits, which will support open science and DIYbio efforts by mass producing such kits in Shenzhen. The cycle from a prototype to artisan object and a DIY, mass produced kit creates these unexpected innovation networks between Switzerland, Indonesia and China, and in this project we can witness the emergence of the first Indonesian DIY kit offered to the global geekdom to enable science in the Global South.

Casablanca of Hardware: Shenzhen

The crucial role in geek diplomacy and in the emergence of the "public of tinkerers" surrounding OSHW plays an important city in the Southern China's Guangdong Province - Shenzhen, which fuels these alternative R&D networks. It is the electronics manufacturing capitol of the world, which is part of a so called Special Economic Zone[20] with tax incentives, relative autonomy, and a close connection to Hong Kong and Taiwan. It is a special place, because it caters the needs of not only large multinational companies and SMEs, but also hardware start-ups, which play an important role in defining the emergent "Create in (or with) China" approach to innovation (Lindtner and Lee 2012). The factories in the region are able to meet the needs of corporations, but also small start-ups, and to create products for both, developed and developing countries, for the most strictly patented and most open sourced if not pirated, shanzhai (Lindtner and Lee 2012) and gonkai (Huang 2013) mobile phones and innovation networks related to them. Shenzhen's infrastructure also feeds the newly emergent R&D networks around the hackerspaces when they need to scale their projects by simplifying and professionalizing their design.

Shenzhen from this perspective is something of a technological version of the 1940s Casablanca depicted in the famous Michael Curtiz film noire. It is a relatively neutral zone, where everyone can come, work on a prototype and scale its production by engaging with various unexpected networks. One example could be the network between the global hackerspaces and OSHW developers, which is fueling the emerging hardware start-up scene

[18] Documentation of Baby GNUSbuino Tropical: https://www.facebook.com/photo.php?fbid=10200667640320218&set=a.10200400213394712.201694.1437047270&type=1&relevant_count=1
[19] http://www.seeedstudio.com/
[20] http://en.wikipedia.org/wiki/Special_economic_zone

in the first, 2011 hardware accelerator, HAXL8R[21]. Another unexpected network was created through the residencies organized by a famous hardware hacker and developer, Bunnie Huang[22], who in 2012 brought MIT students to work on their projects in Shenzhen and to create connections with the local manufacturers. While HAXL8R incubated over twelve projects in the last two years, Bunnie's network created one of the most innovative design projects in recent years, the so called Circuit stickers[23], which are changing the ways we think and interact with paper, writing and electronics.

These unexpected innovation, but also geopolitical networks in Shenzhen are often crowdfunded over Kickstarter and similar platforms, but also connected to various hackerspace scenes. They defy the fearmongering logic of media representations of China as a place, which lacks respect to IP law and steals every good design idea to reproduce it cheaply. They enable unexpected geopolitical networks and economic models to appear. The developers from the Bay area, but also East coast and many other countries, are flocking in Shenzhen, cooperating and defining a completely different model, for which we are using the metaphor of Casablanca, but other people, like the CEO of Seeed Studio, Eric Pan, described as the "Hollywood of hardware products" (Gomba 2013). The hardware hackers and geeks in Shenzhen are forming their own cosmopolitan scene, which is supported by local companies, such as Seeed Studio and their aspiration expressed in their famous label “Innovate with China”. While in the last few years, Seeed Studio emerged as a global, open hardware facilitation company, which works with EU and U.S developers, in 2013 it is starting to notice developing countries in the region. It is trying to support open science and DIYbio prototypes, such as the microscopy kit in Indonesia, but also the emergent hackerspace scene in Nepal by inviting the members of hackerspaces to the Maker Fair in Shenzhen in April 2014 for workshops and consultations. In this sense, the hackerspaces and the OSHW are becoming important tools of geopolitics and science diplomacy (Burns 2013), which involves new actors and opens new possibilities of connecting politics and design.

The OSHW projects started by various hackerspaces around the world naturally gravitate to Shenzhen, where they are able to scale their production and transform into sellable DIY kits. The first successful example, which embodies the new innovation cycle from a prototype connecting various hackerspaces to a crowdsourced DIY kit produced in Shenzhen, was the Safecast[24] project. The DIY radiation monitoring prototypes were designed in 2011 by an international community in Tokyo hackerspace with a help of the hackerspace communities around the world (Kera, Rod and Peterova 2013). While the prototype was developed in Tokyo, the DIY kit was later produced in Shenzhen, from where it is distributed around the world. The project started shortly after the Fukushima disaster as one of the first example how hackerspaces can respond globally and enable the public to gather independent data. Over the years it developed into a professional, non-profit organization, which is improving the industry standards in radiation monitoring and working with established companies, such as International Medcom Inc. The cooperation with Medcom also shows that a successful DIY kit is often a combination of open source and patented technologies, often

[21] http://haxlr8r.com/
[22] http://www.bunniestudios.com/
[23] http://chibitronics.com/
[24] http://blog.safecast.org/

because some part of the design is easier to outsource or it is legally less challenging to cooperate with a friendly patent owner. In the case of the final, bGeigieNano Geiger counter, it was mostly designed by Bunnie Huang and the community around Safecast with a part (iRover high voltage supply with “front end” to process signal from GM tube) owned and supplied by Medcom, who also produces and distributes the final kit (Huang 2012) . OSHW is a tool, which simply supports global projects and new innovation networks, which enable a larger involvement of citizens in the R&D process.

The interaction between design and (geo)politics behind such projects supports a form of geek diplomacy, which embodies the potential of innovation networks to influence politics through the so called "science diasporas". Recently this was reflected in a blog post by the AAAS Center for Science Diplomacy as the emergence of a "new architecture of cooperation" enabling countries to "invent, create, innovate, and solve problems together": *The near monopoly of governments in the management of international affairs has certainly been broken. Diaspora networks, like nongovernmental organizations, civil society groups, and multinational corporations, are increasingly important and influential actors in international relations. Science diasporas are vital to a new architecture of cooperation that will allow us to invent, create, innovate, and solve problems together.... There is no single formula for developing and growing a science diaspora network as a platform for cooperation. Each will be a unique outcome of a country’s culture, history, international relations, political system, economic development, and geography.* (Burns 2013)

The geek diplomacy democratizes R&D by involving citizens and new actors in funding and learning about technology, but also by enabling innovative networks across various institutions and regions to appear. The collaborative work on original ideas combines resilience with innovation, practical, solution driven projects with creative and explorative prototypes, and even open source and patented technologies. Shenzhen seems to attract these entities, which are already global and complex, either multinational corporations, such as Apple, or geek networks, such as Safecast, or open biology networks, such as Hackteria, which connect organizations and individuals from around the world. In the case of Hackteria it is a network between Indonesia, Singapore, India, Switzerland, UK, Germany and Slovenia, where members are based and international workshops happen. The Hackteria open science protocols, but also open hardware tools for laboratory equipment follow the OSHW logic of development, which we described in the case of Safecast, and soon we will probably see more research in developing countries based on these tools.

Political and Technological Empowerment over OSHW

The political and technological empowerment of individuals and communities over OSHW is best illustrated by the various Do-It-Yourself (DIY)radiation monitoring devices developed by Safecast. The cycle starts with a prototype, which is developed into a kit by involving citizens through crowdfunding campaigns, but also workshops, in which people learn how to use it or develop it further. At the same time, the prototype was professionalize by engaging with existing companies producing Geiger counters, to improve the quality and comply with standards, which is not necessary a question of open source. The DIY Geiger counters during this whole cycle of prototyping, testing and reiterating enable citizens to gather and share independent data on radiation and to take an active part in discussing

policy related to the future of nuclear energy (Kera, Rod and Peterova, 2013). The latest, bGeigie nano, received more than 100 000 USD in 2012 as a support over the crowdfunding platform Kickstarter from anonymous and global community of "backers", who decided to invest and support the quest for independent and accurate data. Another of these projects, Bike 2.0 or lately a project for a drone is taking the idea of citizens' monitoring of atmosphere a step further by creating a sensor platform for radiation and air quality for bicycles and drones, innovating the function of this everyday transportation tool, but also rethinking the future.

Over a period of two years, the initial ad hoc network for radiation monitoring transformed into a global non-profit organization supporting open measurement and publication of various atmospheric data, but also the cooperation of citizens-tinkerers with various regulatory bodies to protect the health of their environment. The OSHW supports efforts for independent measurement of data over custom build, DIY tools, where it is crucial to discuss their accuracy and calibration by interacting with existing regulatory bodies and established industry players. This is becoming a common strategy as we can see from other similar projects around the world, such as the Czech based platform Kanarci[25], but also the popularity of sensors and tools for monitoring in OSHW marketplaces, such as Libelium[26] or Seeed Studio (Klosowski 2012).

While similar "humanitarian" hardware projects (Akiba 2011) demonstrate the social and political possibilities of the emergent tinkering public, numerous other OSHW projects are less specific in terms of their agenda. Prototypes and kits provided by services, such as Adafruit[27] and Sparkfun Electronics[28] in the U.S., Seeed Studio in China, and various hackerspaces around the world often serve educational and entertainment purposes. Indirectly, however, they connect politics with design by creating conditions for the public of tinkerers to take new challenges. OSHW tools and kits help amateurs to learn how sensors and basic electronic components work, to customize existing products, and to eventually build prototypes, which tackle various issues from health to environmental monitoring, prospecting, and building independent infrastructure.

Projects, such as "TV-B-Gone Kit"[29] for switching off annoying LCD screens in public spaces, or power monitoring systems, such as "Tweet-a-Watt"[30], enabling control over electricity consumption, but also various robots, drones and wearable technologies are just few examples, on which we can also follow the connection between politics and design. In a playful manner, these kits enable users to think creatively about the function of the public space and test simple ideas of how to regulate consumption. These are not miraculous solutions to any social, political and economic problem, which is usually promised by big corporations like Cisco, Intel etc. when talking about new technologies. They are neither just simple tools for discussion and deliberation on what is the proper course of action, which is often what we think citizen empowerment means. The main role of these

[25] http://www.kanarci.cz/
[26] http://www.libelium.com/
[27] http://www.adafruit.com/
[28] https://www.sparkfun.com/
[29] http://www.ladyada.net/make/tvbgone/
[30] http://www.ladyada.net/make/tweetawatt/

prototypes is to provide experiences of how design relates to politics and how by democratizing the knowledge about building technological infrastructure can help people modify tools and change some everyday practices or even cooperate with regulatory bodies and policy makers. The OSHW tinkering is also enabling citizens to imagine the future and to work together on various versions of how we want to use and live among emergent technologies (wearable, drones, and robots).

The Public of Tinkerers: Trias Politica versus Experimental Policy

OSHW simply assists the technologically savvy public to tackle local and global challenges and to test potential futures rather than to only discuss issues or delegate decisions. OSHW is a technological platform for collaboration and prototyping, which influences both, policy and design, politics and technology. It enables public participation and global engagement in various issues through collective tinkering, which is not bound to any immediate patent rules or geopolitical interests. The informal collaboration between a global group of hackers, makers, experts, but also citizens and amateurs happens both online and offline through workshops and its main function seems to be to involve more actors on such grassroots level.

The radiation monitoring efforts showed that by teaching volunteers to connect Arduino boards with sensors and electronic components, and later by simplifying this through custom made PCBs and kits, we can empower various groups to gain independent data and to make decision and engage with politics on this infrastructural and material level. The whole OSHW process of design, distribution, customization, learning and prototyping encourages citizens and amateurs to take an active part and interact on every step of the R&D process with the experts, but also hopefully even policy makers and industry players.

In order to explain the potential of these techno-political practices and networks as an emerging public sphere of tinkerers, we need to discuss two important aspects of how OSHW connect politics and design. The first is the empirical aspect, which we discussed in the previous chapters, and we believe more needs to be done to understand the local and the geopolitical networks around OSHW, which integrate various actors. The second is conceptual, on which we would like to reflect upon, since the relation between politics and design forces us to rethink making as a political and ontological category in philosophy. While the empirical part of our research describes the global and local activities of the existing public of tinkerers, the theoretical part establishes a framework for defining experimental policy related to the use of prototypes as policy tools. It also problematizes the notion of “trias politica” and the separation of powers as an ideal of (western) politics, which is based upon Plato’s Republic.

Plato's Republic serve as a bases of our political ideals and thinking about policy. We tend to separate design from politics and making from thinking, because we define regulation (governing of the city) as an insight into the natural and healthy unity of the individual and the social body (city) rather than as a messy process of experiments and decision making. Justice in Plato’s Republic (Book IV.6—IV.19.) is achieved only through the right use of our faculty of the contemplative and theoretical reason, which needs to be employed by the right class of citizens, rather than as something democratic, experimental, collaborative and

uncertain, which is open for testing by different citizens and part of negotiation between different actors. We need a separation of powers and expertise in order to have the right insight for the right action. But what happens in a situation of crises with many risks and uncertainties related to the use of various technologies, where no one can achieve the right insight and actions have uncertain results? Is such separation of powers a useful policy for a society, which needs to distribute the effects, opportunities and risks, which every new technology presents?

The collective prototypes developed by citizens over OSHW shows a different model of policy, which is not based on the separation of powers, but on the ability to support and engage with new actors. The OSHW prototypes define regulation as an experiment and iteration rather than supervision and insight. The ontology behind this attitude is close to the recent materialist positions, which claim agency of non-humans defined not as a pure fact or an objective reality, which needs an insight, but as an actor with which we negotiate interests, relations and actively co-create rather than embody some future (Braver 2007; Bryant, Harman and Srnicek 2011; Ennis 2011; Graham 2002, 2005, 2010). The intricate connections between society and technology based on these new materialist and realist positions lead us to our main thesis, which is to define regulation and policy as experimental design. Technologies as new actors with agency need to be integrated as much as deliberated and negotiated. By allowing other actors to experiment with them we adapt and check the comfortable levels, we can even change them, rather than simply imposing them or mediating them. In this sense, the OSHW enables technological empowerment, which is material, discursive and social. It performs a new metaphysics, but also politics of prototypes, where we express our political values and insights by building and cooperating over new tools. The emergent (Re)public of tinkerers views the political ideal as something we need to co-create and design rather than embody like some true nature of our soul or society.

Separation and Hybridism of Technological Powers: from OSHW to Patented and Hybrid Hardware

Open Source Hardware (OSHW) supports decentralized and participatory approaches to innovation through kits, which make technology accessible to customization for various niche communities. The kits support distribution and further development of OSHW, by providing the components and the instructions needed to build prototypes, which can motivate further development. These kits democratize technologies and offer a platform for anyone to innovate. They define new relations between experts and amateurs, innovators and producers, technologies and contexts (niches), but also unique geopolitical networks, which ignore the common East-West stereotypes and enable R&D in new places.

The hardware innovation, which is concentrated in Shenzhen, China, shows the complex geopolitical networks behind the new "public of tinkerers" seeking technological and political empowerment. Scholars are starting to notice Shenzhen as an important center, where design and politics work in a different way from what we would expect when we discuss innovation. Shenzhen is the place where the possibility of "created" and "co-created" and not only “made in China” is probed (Lindtner and Lee 2012) and innovation is happening outside the patented versus open sourced framework. Silvia Lindtner and David

Lee summarized well the connection between copycat production (shanzhai) and OSHW maker cultures and the various forms of hardware we can encounter: *Drawing upon shanzhai innovation, China's hackerspaces argue for an alternative version of 'created in China.' Rather than proposing to overcome manufacturing for the sake of knowledge production, they offer a view that China's existing manufacturing infrastructure could be used to accomplish in practice what so far has been a political vision*. (2012)

The dynamic ecology of local hackerspaces, open hardware accelerator (HAXLR8R) and residency program for MIT graduates organized by Bunnie Huang transformed Shenzhen into a unique cosmopolitan innovation hub, which successfully ignores the geopolitical stereotypes and demonstrates how "created in China" is becoming a reality, but it "takes a slightly different form from what politicians, policy makers, and large corporations envision the future of innovation." (Ibid.) Shenzhen represents well the paradoxes, but also the pragmatism behind hardware innovation as a model of experimental policy connecting design with politics: patented, pirated, copied and open sourced technologies coexist and influence each other in a complex milieu. The entrepreneurs from all around the world freely explore new political and economic networks and models for their projects.

While some prototypes and kits, such as the DIY Geiger counters enabled a global public of tinkerers, which engage with their governments through their own data and tools, other have a less obvious political effects. What is undeniable however is that the hardware innovation in Shenzhen is developing its own unique geopolitics of tinkering. Pragmatic and utopian at the same time, the OSHW tools are becoming both a product and a medium for self-reliant and independent communities around the world. OSHW is after all behind projects, such as the Open Source Ecology[31] village in Missouri, US, the mentioned Micro/Macornation villages by HONF around Yogyakarta, or the emerging projects in Nepal, such as already mentioned Karkhana, but also the venture firm called Biruwa[32]. The organizational and economic experiments behind OSHW are often related to attempts to integrate patented technologies and to experiment with new institutional models inspired by the hackerspaces and coworking culture.

The unique geek geopolitics surrounding experiments with separating and hyrbridizing "technological powers" behind OSHW and patents is well illustrated on the example of Haddock Invention[33], another company based in Hong Kong, but operating also in Shenzhen, which together with an affiliate, Mantis Shrimp Invention[34] from Manila, form what they call a network of workshops and garages or rather "highly talented invention teams". Their unique model combines the hacker ethos (even if it their hardware is not necessarily open source) with crowdfunding, but also elements of traditional business practices, such as patents and multinational, networked structure of their business model. Their network of garages around Asia, EU and South America efficiently mocks the corporate pan-global structures. More importantly their disruptive, low tech prototypes are trying to provide solutions to both developed and developing countries in terms of energy efficiency.

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[31] http://opensourceecology.org/
[32] http://www.biruwa.net/
[33] http://www.haddockinvention.com/
[34] http://manilamantis.com/

The whole network of these garages was started by MIT graduates, Alex Hornstein and Shawn Frayne, who believe in cooperation with local teams of tinkerers in developing countries as a model for future "clean confluent technologies", such as low tech solar panels and wind turbines (for powering small devices, mobile phones etc., which are critical for developing countries). Their green energy prototypes can power wireless sensor nodes for environmental monitoring, but also mobile phones and various other infrastructure, which improves the lives of people all around the world. It is making everyone energy independent over technology, which is disruptive both economically and politically. They show how technological and social innovation are closely connected in the present and how it is important to create such complex networks around prototypes: *We're developing this network because we believe paradigm-shifting, disruptive, confluent (insert punditry here) technologies, emerge from a different innovation machine than has traditionally been the engine of progress in the past. These new inventions are not churned out the "invention factories" that Edison created in 1876, where hundreds of engineers worked twenty hour days on the same punch clock under one roof. Nowadays, the biggest problems aren't near the wealthiest markets, and creativity is too spread out across borders.* (Hornstein 2012)

These "cells" in what they hope will become "a global invention organism — the Ocean Invention Network" (LeCompte 2013) are small teams of 4-5 people from the both sides of the wealth divide, which are simply testing new models of manufacturing, R&D and business. They embody an interesting model of innovation, where graduates from MIT go to Shenzhen or even the developing countries in the region to build prototypes by working closely with local manufacturers, and then creating a company in Hong Kong to make products available for markets in Thailand, Philippines etc. The R&D in Shenzhen may seem contra-intuitive because of limited patent protection, but this less regulated space is very supportive of innovation and experiments between patented and open sourced, hybrid technologies, and it is also an excellent spot for creating relations with various countries in the region.

Politics of Global Prototypes

We discussed how OSHW is connecting design and policy by enabling citizens to get direct data and support citizen participation in decisions making on nuclear technology or pollution. we also mentioned that it supports new business models and organizations, which form unique geopolitical networks and value chains. OSHW in this sense is a complex assemblage of technologies, design principles, forms of licenses, which disrupts not only our ideas about the innovation cycle, but also the common geopolitical divisions we use when thinking of China. The close connection of OSHW to alternative R&D centers (garages, hackerspaces, incubators) is also a ground which we are witnessing and emerging tinkering public. These OSHW and hybrid prototypes connecting politics and design embrace the values of customization, openness and cooperation as deontological and not only pragmatic and utilitarian principles for any action. These prototypes are neither "invented" nor "adopted" and "disseminated" by clearly defined actors. They are not imposed nor protected by any government or industry actors, but they manage to negotiate their own forms of innovation cycle and policy relations.

OSHW prototypes are more like dreamworks, which involve various (and sometimes conflicting) online actors, publics and global communities formed around them in various stages of their design, creation and distribution. These processes are closer to such unconscious and even biological phenomena of crosspollination and symbiosis rather than to well-defined economics of launching a product or doing an IPO and the whole politics of licensing and patenting . They may not resolve our present resource-based conflicts, but they do offer interesting case studies of how we can transform political and economic frictions into opportunities. Their creative and paradoxical potential defines geek diplomacy and politics based on maker's knowledge in independent, but often ad hoc and mobile R&D centers. The garages in Delhi, Shenzhen and Manila, together with fablabs, hackerspaces and similar institutions around the world enable prototypes, such the strange nonturbine wind generators (Hong Kong/Hawaii), underwater drones (Octo23 in Paris) or drones operated by EEG (Shenzhen hackerspace) etc.

Developing countries, such as the Philippines or Thailand present ideal sites for what inventors, such as Shawn Frayne and Alex Hornstein , called "confluent technologies" and "technological magic that happens when challenges faced in developing countries meet the challenges faced in wealthy countries" (Hornstein 2012). Disruptive technologies, such as mobile payments (used in Philippines, Kenya), or low tech and cheap diagnostic tools were actually designed and created in these places and only later adopted in the so called "develop nations". The innovation in developing countries is simply more radical because of scarcity of resources, but also extreme conditions, which push the innovators to develop more resilient and original solutions: *Whenever new products are developed to serve new customers at radically different price points, something wonderful that happens – a rupture breaches the status quo, where incremental innovation produced by incumbent industry giants is wiped away by a leap forward. …These confluent technologies were developed to solve some challenge in emerging markets, under the pressure of cost constraints very different from the constraints in Silicon Valley. Emerging markets are the breeding ground for new innovations that will topple industries, not despite their constraints but because of them. For the first time, the lack of electricity, scarcity of clean water, and the great need for medical diagnostics in the small village of La Borgne, Haiti can force into existence new solutions that have the power to overturn multi-billion dollar empires across the economic divide in rich cities like Tokyo and San Francisco. That is what the Ocean Invention Network is all about – teasing out great inventions from the confluence, and making some trouble along the way*. (Frayne 2012)

The network of garages enabling disruptive innovation, which resolves some first and third world problems, also explores unexpected networks around OSHW and Shenzhen. Through these global and crowdsourced processes of financing, designing and manufacturing products we are testing new forms of geopolitics. The flow of capital, talent and tools around OSHW and Shenzhen created a precedent, which connects politics and design and provokes us to take the next necessary step: How to make this innovation more just and help the people in the region who suffer from the consequences of this rapid development? How to involve the people in the regions, where minerals are mined for all the electronics breaking the divide between the worlds? The emergent public of tinkerers has an ambition to influence both local and global governance, but are they ready to tackle more difficult issues? Is there any public of tinkerers and can they serve as a new model for governance?

The empirical material we discussed, which surrounds OSHW networks, is giving us some hope for new forms of governance, but the work, which needs to be done is related to the conceptual and genealogical origins of our concepts of governance.

The (Re)public of Tinkerers

Discussions about the "public sphere" in Media studies (Lund and Livingstone 2013) or the "public participation and deliberation" (Brown 2009) in Science, Technology and Society studies (STS) are important points of reference for formulating the aspirations of the emergent "public of tinkerers". They bring two very different views of the political role and governance of technologies. In the STS field we are discussing how to support the public on deliberating upon various technologies, which are seen as an object of policy decisions. In communication and media studies, technologies are means rather than objects of public deliberation. The public of tinkerers, which we are trying to define, has elements of both, it relates to technologies as objects, but also as means of citizen participation and deliberation. To this we can add a third function, which is "hacking" and modifying technology to support communities, they are not only objects nor media, but something that is designed and assessed by citizens themselves.

Thanks to the technologies enabling prototyping and collaboration, the "public of tinkerers" is forming around OSHW in a manner close to what Christopher Kelty (2008) describes as a "recursive public". He is describing the type of social, political and technical activities of geeks surrounding the open source software movement, which are reflective and normative at the same time. While he emphasizes the iteration as a reflective moment, through which the technology becomes an object of our "moral imagination", other recent anthropologists and designers emphasized the close connection between discursive and material practices. When discussing 3D printing and OSHW activities in the hackerspaces Ratto and Ree (2012) make this connection explicit, and Ratto's recent concept of critical making (2011) transforms this into a principle. The public of geeks and tinkerers is also discussed in Coleman's important work on hackers and open source software (2012), and in Eric Paulos's "Manifesto of Open Disruption and Participation" (2009), where he embraces the creation of "an entirely new form of citizen volunteerism, community involvement and participation" through environmental monitoring, which can "effect real political change" (Ibid).

Kelty's technologically savvy public connects the "moral imagination" with the "technical infrastructure" by recursively working and improving both. While his concept does not include experimenting, the recursive aspect points to the importance of the iterative design processes in forming decisions on prototypes, infrastructure and policy. It is a public, which uses the "*activities of making, maintaining, and modifying software and networks, as well as the more conventional discourse… to argue about technology, but also through it... They express ideas, but they also express infrastructures through which ideals can be expressed (and circulated) in new ways*" (2008: 3). The crucial point for Kelty is that the connection between technology and society or the "operating systems and social systems" (2008: 6) is about the imaginary potential of the public sphere, which is almost opposite to the ideas of the agora - a public space as a common space of some action: *In fact, if the public sphere exists as more than just a theory, then it has no other basis than just such a shared imagination of order, an imagination which provides a guide against which to make judgments and a map for changing or achieving that order. Without such a shared*

imagination, a public sphere is otherwise nothing more than a cacophony of voices and information, nothing more than a stream of data, structured and formatted by and for machines, whether paper or electronic. (2008: 11)

The "recursive" here is basically synonymous to the shared, imagined community, which is a concept important for Charles Taylor (2004) when describing the crises in present liberalism. Kelty is trying to apply Taylor's shared ideal of the "moral and social order" and social imaginary to technology , but the main problem remains that for Taylor this is something, which should never be reduced to any material condition. For Kelty, the work of the geeks and hackers actually proves that similar ideals are never reduced to the technological infrastructure, but that the networks are critically assessed from the point of view of these ideals and basically forced to improve. The hackers perform the social imaginary over the technologies, which seem always somehow uncooperative. In this sense, both Kelty's and Talyor's positions actually recall the Plato's Republic tradition of connecting the political with the right insight instead with any practice.

While we can agree on the importance of the autonomy and certain transcendence of the public sphere (imaginary) as a necessary condition for creating a strong normative ideal for any community and any action, we do not see a strong reason to insist on its "non-material" ontology and connotations. The public of tinkerers around OSHW is closer to what Kelty (2008) describes in his "Internet Silk road" chapter, where he followed a specific group of geeks around their Silk-list (2008: 11) in Bangalore. On this example rather than on his notion of a "recursive public" he demonstrated the global and hybrid networks, which are not just questions of a “moral ideal of order and shared imaginary” placing the public outside the material conditions, markets and simply limits of the world. These networks are clearly a practice, which involves non-human entities and materiality, and whose agency can acquire certain transcendent or sublime qualities of the normative imaginary.

The notion of the "public of tinkerers", which we use to describe the OSHW global efforts around open science, but also alternative R&D networks, is also close to Jürgen Habermas’s concept of the “public sphere” as discussed in “The Structural Transformation of the Public Sphere – An Inquiry into a Category of Bourgeois Society” (1989), and a similar 19. century notion of the public in Gabriel Tarde (Katz 2006). Habermas' concept of the “public sphere” discusses not only the press, but also the importance of public and social spaces for deliberation, such as coffee houses. He emphasizes the importance of free discussion and negotiation or a " discursive space in which individuals and groups congregate to discuss matters of mutual interest and, where possible, to reach a common judgment." (1989) Where we differ from these concept of the public sphere is the issue of rationality, which similarly to the issue of some collective "imaginary" presents a very strong normative notion. The public of tinkerers in our opinion as achieving identity through experimenting and negotiating both, technology and ethics, design and politics, rather than setting in advance an ideal of what these prototypes bring to the community.

While Habermas is often discusses in any analysis of the public sphere, 1903 “Laws of Imitation" by Tarde (Katz 2006) is forgotten. It discusses how the press and the media help citizens to form a rational collective identity described as the “public” against the spontaneous and irrational behavior of the crowds and masses. The press provides

material for conversations among citizens, who exchange their opinions in various public spaces and then provide feedback through the media back to the government. The public and the press constitute what Tarde calls the "brake on government" (Katz 2006) as much as prevention against the wild irrationality of the masses. Media support the discursive and reflective practices, which form the public against the irrational fears and immediate reactions of the crowds: "*whereas a heterogeneous crowd arises from momentary and single-minded interaction around some event, the public is a more homogeneous, more contemplative product of a press that creates a union of readers around issues …* "(Katz 2006) The press simply helps the public to define various agendas, discuss and clarify opinions and issues, and then translate them into actions, which are political, artistic, etc. The public of tinkerers engages with the discursive and material practices in parallel and produces tools and documents, which are open for discussion and further negotiations and tinkering.

Tinkering as a Normative Engagement with Technology

To explain this parallel and not only recursive or discursive involvement with social and technical innovation around tinkering, which leads to the formation of the public of tinkerers, we will use the "Open Source Ecology" project (A Network of Farmers, Engineers, and Supporters Building the Global Village Construction Set). Their "Global Village Construction Set" (GVCS) prototype applies open source hardware to support sustainable and autonomous communities anywhere around the world: "*modular, DIY, low-cost, high-performance platform that allows for the easy fabrication of the 50 different Industrial Machines that it takes to build a small, sustainable civilization with modern comforts*". [35] The GVCS prototype is an object but also a medium for rethinking the future of agriculture and sustainable communities. It helps tinkerers and farmers around the world to discuss and deliberate upon the future of their own local communities, but also the global society. OSE is building the tools and the community and in parallel it is also testing them at their "Factor e Farm" (FeF) in rural Missouri. The FeF site is an experiment, which "aims to take everything that civilization has learned to date, to create a working blueprint for communities that work" (Ibid).

Connecting the social and technical innovation through such iterations and experiments is what defines the public of tinkerers and their approach to governance. The public of tinkerers is more than a group of consumers (prosumers) or some demographic category (geeks) defined by the tools they use or want to improve. They are stakeholders mitigating the risks and benefits of a particular technology by actively improving it and reflecting upon its effects on their community. They are also citizens who are trying to define new normative goals with these technologies, such as the importance of open society and transparency or sustainable communities. In this sense, they exemplify all the previous notions of the public (communicative, recursive, imaginary), but they add to that an experimental aspect, where risk and uncertain future are something that we all need to take care of. They exemplify, what Daniel Fiorino describes as a "normative" (rather than instrumental or substantive) reason for involving the public in risk and decision making related to technology (1990). If there are only instrumental or substantive goals (even if

[35] http://opensourceecology.org/

they are imaginary or rational), the public is involved through corporate, state and non-government actors, who are trying to gain support for or against certain technologies. True normative goals in a society of risk and technological innovation means to create conditions for empowerment and distributed decision making processes, which are happening in the present over OSHW.

The normative in the case of the present tinkering public is plural and conditional and everything, including risks and benefits, is tested and experimented with rather than assessed in advance. This view of governance based on OSHW and tinkering is close to some concepts, such as "reflexive governance". In order to involve the public in the decision processes about the future, we have to open the multiplicity of technological and social challenges and to create conditions for “plural and conditional” support (Voss and Bauknecht and Kemp 2006: 261), which is also discussed as “grounded perspectives” and “iterative participatory goal formulation”. The public of tinkerers, which use, deliberate and develop new technologies over OSHW can make such “plural and conditional decisions”, which are reflexive: “*independence in risk regulation of scientific research systems increasingly rests on pluralistic engagement, rather than claims to unitary transcendent notions of ‘scientific objectivity’, ‘institutional legitimacy’ or ‘expert or moral authority’. A move from ‘independence through objectivity’, to ‘independence through pluralism’, is this a key feature of more reflexive approaches… in the governance of sustainability”.* (Voss and Bauknecht and Kemp 2006: 255)

While the instrumental and the substantive view of deliberation and social appraisal of various technologies as process of negotiating risk or analyzing impacts (Fiorino 1990, 1995) always emphasize the discourse as something through which the public “speaks” and participates, the normative engagements involve the public on the level of material practices. The emphasis on discourse as means of deliberation and reflection of our future is simply not enough in a situation of risk and uncertainty, where we need tools through which citizens can interpret and interact over data, but also modify and build tools needed for tackling local challenges. The emphasis on discourse is based on the political idea of separation of power, where the sphere of judgment should be always divided from the sphere of action to creates a balance of powers. This separation is in the base of all theories of the public, and only with OSHW we are opening a possibility of a larger involvement of the public in the development and assessment of technologies.

The separation of power as a model of governance is deeply ingrained in our technological policies, but also concepts of the public. It refers back to the tripartite view of the soul and the city in Plato's Republic, where the different activities of thinking, regulating and producing are strictly divided. The policy makers, industry and research representatives, non-government representatives and citizens need to be separated in terms of their specializations, abilities and interests. Regulating, researching and producing are divided even today according to the original model of the soul and the city in the Republic’s book IV. The appetite - eros, the spirit - thymos and the reason – nous are three faculties of living, acting and knowing, which define different classes of citizens (demiurgoi – merchants and laborers, then soldiers and enforcers, and the third class of guardians, from which we recruit the philosopher kings). It should be clear, who is in charge of defining policies and regulations, who provides new ideas and solutions and who produces and distributes the

tools. OSHW collective prototypes and innovation, which involve self-regulation, but mostly concentrates on testing and improving the solutions, seems to ignore this separation of power. The public of tinkerers if closer to the " city of pigs" with its spontaneous justice based on interaction between various actors and to the feverish and luxurious city prone to excesses described in book II. and III. Philosopher Kings and their Kallipolis, which Plato envisions as ruled by the ideal of the contemplative life, seem to be losing their grip on our political imagination in favor of another hero from Plato's dialogues, the Demiurg. The artisan and the craftsman from the dialogue Timaio creates a new universe from chora, by managing the chaos, which has the capacity to create anything into a beautiful and functional well-ordered cosmos. Rather than defining competencies first and acting later, the demiurg 3D prints various blocks from which you can build almost anything. The world he creates is a natural and political unity, similar to what Open Ecology Project envisions with their prototypes, while the Kallipolis is utopia of perfect control of perfect humans, more like a world ruled by some big data policies, which supposedly give us an insight into the truth.

Conclusion

OSHW brings an interesting challenge to the ideas of public sphere, because it enables a public which is not only using tools to discuss a problem or a technology, but also to build tools, apps, hardware and change its conditions. Action and reflection, deliberation and transformation are closely tied together, and normative regulations are formed while building and testing the tools. The public sphere is not just some condition for free deliberation, but something created by the citizen themselves, it is literally “built” and formed through tinkering with OSHW. The ability of hardware to create such assemblages, through which people collaboratively to resolve matters of mutual interest and further open these technologies, while working on the rules of their use, is clearly expressed in the “statement of principles” of OSHW: “Open source hardware is hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design. The hardware’s source, the design from which it is made, is available in the preferred format for making modifications to it.”[36]

The "opening" of the technology as the ultimate goal of the public of tinkerers is also something mentioned by Habermas (1989) in his famous definition of the public sphere, where “individuals and groups to congregate, discuss and collaboratively resolve matters of mutual interest and, where possible, to reach a common judgment, but also protocols, standard and simply open the decision process while opening the technology too.” This opening means discursive and material process, where the digital design files for physical objects are kept open so anyone can buy the components and take part in the development and not only the discuss the tool.

The public sphere of tinkerers furthermore creates opportunities for ad hoc and immediate networks between various actors to develop, which we discusses in terms of geopolitical relations around Shenzhen and the importance of OSHW laboratory equipment in Indonesia. When using OSHW companies, individuals and groups can design and make new

[36] http://www.oshwa.org/faq

tools while deliberating upon their use or other action as we showed in the case of DIY Geiger counters. The only party, which is still lagging the adoption of these tools for policy are the government agencies, which still prefer data driven projects. The challenge for the future is to support more citizens in building OSHW tools as a way for self-regulation or deliberation or even testing of a certain technology. The well-known examples of OSHW, such as Arduino boards (an microcontroller development platform) or the original MakerBot Replicator (a 3D printer) enable individual, communities to design, deliberate and negotiate their needs, and interact with various stakeholders over an issue. We can imagine people building their own machines for voting and defining their own protocols for monitoring food safety and building infrastructure for such purposes.

OSHW is a symptom of our changing attitudes towards technologies, which involve questioning and rethinking the relations between producers and consumers, citizens and regulators, and the emergence of a new type of technologically savvy public. OSHW encourages individual and collective involvements with technologies, which combine political with ontological commitments. In this respect it is close to some recent views of agency in Actor Network Theory (ANT), cosmopolitics, speculative realism, new materialism and object oriented ontology, which rethink politics in relation to objects and processes outside the narrowly defined social sphere and human agency.

Making OSHW prototypes individually and collectively becomes as important as making arguments, debating, voting and appointing representatives when it comes to tackling global challenges related to our environment and health. OSHW simply creates conditions for connecting policy and design and supporting resilience through experiments, in which reflection and deliberation are tied together with action. The OSHW defines the public sphere as a space of tinkerers, which is used not only for discussion, but also experiments with prototypes, which test various technologies and ideas. This often happens in the so called hackerspaces, community driven and coworking, membership supported laboratories for sharing tools and resources needed for research and development, but also education.

This public of tinkerers symbolically marks the rise of the “demiurgoi” against the “philosopher kings” as the rulers of the utopian Kallipolis and it defines governance (policy) as a process of iteration and not only deliberation. Making prototypes becomes a political act of choosing alliances with non-humans across scales and experimenting with new global communities and symbiosis with materials, tools and non-human entities. This emergent (re)public of tinkerers favors experimental approaches to policy rather than policy based on the separation of powers and trust in experts and representatives. It is a policy based on open design principles, which favor the involvement of various new actors and collective decision making rather than expert based judgments and decisions, which needs to be only properly diffused and implemented.

Reference

Carrier, M. 2013. "SOPA, PIPA, ACTA, TPP: An Alphabet Soup of Innovation-Stifling Copyright Legislation and Agreements." 11 Nw. J. Tech. & Intell.Prop. 21 (2013), http://scholarlycommons.law.northwestern.edu/njtip/vol11/iss2/1.

Braver, Lee. 2007. A Thing of This World: A History of Continental Anti-Realism. Evanston, IL: Northwestern University Press.
Brown, Mark B. 2009. Science in democracy expertise, institutions, and representation. Cambridge, Mass.: MIT Press.
Bryant, Levi, Graham Harman, and Nick Srnicek. 2011. The Speculative Turn: Continental Materialism and Realism. Melbourne: Re.Press.
Burns, William J. 2013. " The Potential of Science Diasporas". Science Diplomacy blog, 12.09.2013, http://www.sciencediplomacy.org/perspective/2013/potential-science-diasporas.
Coleman, Gabriella E. 2013. Coding freedom: the ethics and aesthetics of hacking. Princeton: Princeton University Press.
Deleuze, Gilles, and Félix Guattari. 1987. A thousand plateaus: capitalism and schizophrenia. Minneapolis: University of Minnesota Press.
Ennis, Paul J. 2011. Continental Realism. Winchester, UK: Zero Books.
Fiorino, Daniel J. 1995. Making environmental policy. Berkeley: University of California Press.
Fiorino, Daniel J. 1990. “Citizen Participation and Environmental Risk: A Survey of Institutional Mechanisms.” Science, Technology & Human Values 15 (2) (April 1): 226–243. doi:10.1177/016224399001500204. http://sth.sagepub.com/content/15/2/226.abstract.
Frayne, Shawn. 2012. "The birth of confluent technology". Mantis Shrimp Invention blog, http://manilamantis.com/tag/confluence.
Gomba, Davide. 2013. "Arduino goes to Shenzhen: the Hollywood of hardware products". Arduino blog, April 11th, 2013, http://blog.arduino.cc/2013/04/11/arduino-goes-shenzen.
Habermas, Jü rgen 1989. The structural transformation of the public sphere: an inquiry into a category of bourgeois society. Cambridge, Mass.: MIT Press.
Harman, Graham. 2002. Tool-Being: Heidegger and the Metaphysics of Objects. Chicago: Open Court
Harman, Graham. 2005. Guerilla Metaphysics: Phenomenology and the Carpentry of Things. Chicago: Open Court.
Harman, Graham. 2010. Towards Speculative Realism: Essays and Lectures. Winchester, UK: Zero Books.
Hornstein, Alex. 2012. "The Solar Pocket Factory: an Invention Adventure". Blog, http://www.kickstarter.com/projects/alex9000/the-solar-pocket-factory-an-invention-adventure/posts?page=3.
Huang, Bunnie. 2013. " Safecast Geiger Counter Reference Design." Bunnie's Blog, http://www.bunniestudios.com/blog/?p=2218
Katz, Elihu. 2006. "Rediscovering Gabriel Tarde." Annenberg School for Communication Departmental Papers (ASC), http://repository.upenn.edu/cgi/viewcontent.cgi?article=1278&context=asc_papers.
Kelty, Christopher M. 2008. Two bits: the cultural significance of free software. Durham: Duke University Press.
Kera, Denisa. 2012. "Hackerspaces and DIYbio in Asia: connecting science and community with open data, kits and protocols." Journal of Peer Production, 2012;2, http://peerproduction.net/issues/issue-2/peer-reviewed-papers/diybio-in-asia.
Kera, Denisa, Rod, Jan, Peterova, Radka. 2013. "Post-Apocalyptic Citizenship and Humanitarian Hardware." In Nuclear Disaster at Fukushima-1: Critical Reflections at the

Crossroads of Science, edited by Richard Hindmarsh, 97 - 115. Routledge Studies on Science, Technology and Society. Routledge.
Klosowski, Thorin. 2012. " Monitor Your Air Quality with a Cheap Sensor and an Arduino." Lifehacker, 4/20/12, http://lifehacker.com/5903710/monitor-your-air-quality-with-a-cheap-sensor-and-an-arduino.
LeCompte, Celeste. 2013. " Introducing the Ocean Invention Network, a super lab trying to save the world." Gigaom, Jan. 7, 2013, http://gigaom.com/2013/01/07/introducing-the-ocean-invention-network-a-super-lab-trying-to-save-the-world.
Lunt, P., and S. Livingstone. 2013. “Media Studies’ Fascination with the Concept of the Public Sphere: Critical Reflections and Emerging Debates.” Media, Culture & Society 35 (1) (January 17): 87–96. doi:10.1177/0163443712464562.
http://mcs.sagepub.com/content/35/1/87.extract.
Rogers, Everett M. 1983. Diffusion of innovations (3rd ed.). New York: Free Press.
Paulos,Eric. 2009. "Manifesto of Open Disruption and Participation,"
http://www.paulos.net/papers/2009/manifesto2009.html
Plato. The Republics. The Internet Classics Archive. Translated by Benjamin Jowett
http://classics.mit.edu/Plato/republic.html.
Plato. Timaeus. The Internet Classics Archive. Translated by Benjamin Jowett
http://classics.mit.edu/Plato/timaeus.html .
Ratto, Matt. 2011. “Critical Making: conceptual and material studies in technology and social life.” The Information Society 27(4).
Ratto, Matt, and Robert Ree. 2012. “Materializing Information: 3D Printing and Social Change.” First Monday. http://firstmonday.org/ojs/index.php/fm/article/view/3968/3273.
Siagian, Andreas. 2012. "Juxtapose through media – DIY microscope webcam for Hemocytometer collaborative research." Squaresolid – lifepatch.org, https://andreassiagian.wordpress.com/2010/03/11/juxtapose-through-media-diy-microscope-webcam-for-hemocytometer-collaborative-research.
Siagian, Andreas. 2013. " DIY microscopy stage kit – Indonesian clone [hack & make]." Squaresolid – lifepatch.org, http://andreassiagian.wordpress.com/2013/02/24/diy-microscopy-stage-kit-indonesian-clone-hack-make.
Voss, Jan, Dierk Bauknecht, and René Kemp. 2006. Reflexive governance for sustainable development. Cheltenham, UK: Edward Elgar.