Fabricating Labs

Guidelines for designing and planning Fab Labs, Makerspaces and Innovation Facilities

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The (Fabulous) Beach Lab

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About the author

My name is Francisco Sanchez Arroyo, I am a MSc.Civil Engineer with specialty in Structural Engineering by the Polytechnic University of Catalonia. I am also an accredited LEED AP in Building Design and Construction by the GBCI, Fab Academy graduate and Bio Academy graduate. In late 2012 I quit my Real Estate job to focus in the maker movement and stablish my own innovation space, The Beach Lab. Passionate about education, technology, innovation and the environment, I balance my global citizenship with the love of my 2 beloved sons. Please feel free to reach me with any questions or comments about any of these topics.

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Disclaimer

This guide is work in progress, check the build date at the cover page. It is not yet complete and might contain missing and/or incorrect information. Handle with care.

1 Introduction

Are you planning to set up a Fab Lab or Makerspace? A common mistake is starting by placing machines and then figuring out the rest later. But did you think about the workflow around each machine? Are the other uses inside that room compatible with your process? This Guide is intended to help identifying those workflows, cover the basic requirements and to avoid having future problems related to inadequate planning.

As a member of a global network of interconnected labs, I have had the opportunity to visit, set up, fix and operate many fab labs all around the world, including mine, The Beach Lab. I not only help fab labs to streamline the setup, operation and training of their facilities. I also guide them to create better spaces that are not just rooms with a bunch of equipment, but promote the development of a strong sharing community and interaction of its members.

While this document will need to be further developed, it will settle the foundations for the work to be elaborated in your planning process.

2 The Ideal Layout

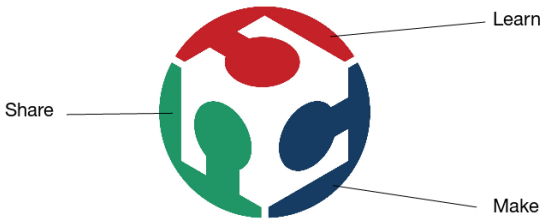
Many times I receive this question: *What is the ideal Fab Lab layout?*

2.1 The short answer

It does not exist such a thing.

2.2 The long answer

There is not and ideal layout for a Fab Lab. Every fab lab has its owns singularities that make them unique spaces. But what makes all fab labs so great orbits around a very simple idea that is represented in the three men holding each one shoulder in Fab Lab logo. *Fab Labs are places to learn, to make and to share.*



And these three basic concepts, should have a physical representation in the layout.

2.3 Principles and Values to foster

Apart from that, there are some key values we will try to embed into the fab lab. Since these values have a lot to do with innovation:

Learning by doing.

Flexibility. The spaces should serve many purposes. A flexible design can virtually multiply the space in your lab, making it suitable for many different activities. I was glad to see some furniture and machines on wheels. It also requires incorporating hanging power cords, open ceilings and flexible ducts for lasers exhausts.

Modularity. The space should be able to grow or shrink as the needs of the lab progresses.

Sustainability. This is a key and fundamental concept that it's behind the origin of fab labs.

Sharing and collaboration. The spaces we create should encourage people to cooperate together.

Innovation. Fail safe environment for experimentation.

Real use case applications.

If you want to send a powerful message, you must show and transmit these values through every aspect in the fab lab, from the workshops, to the layout, to the furniture, to the materials and to the staff.

Figure 1: Lamps fabricated using tools in the lab as lasercutters and upcycled materials.

Figure 2: Existing furniture can be hacked to promote customization and collaborative designs.

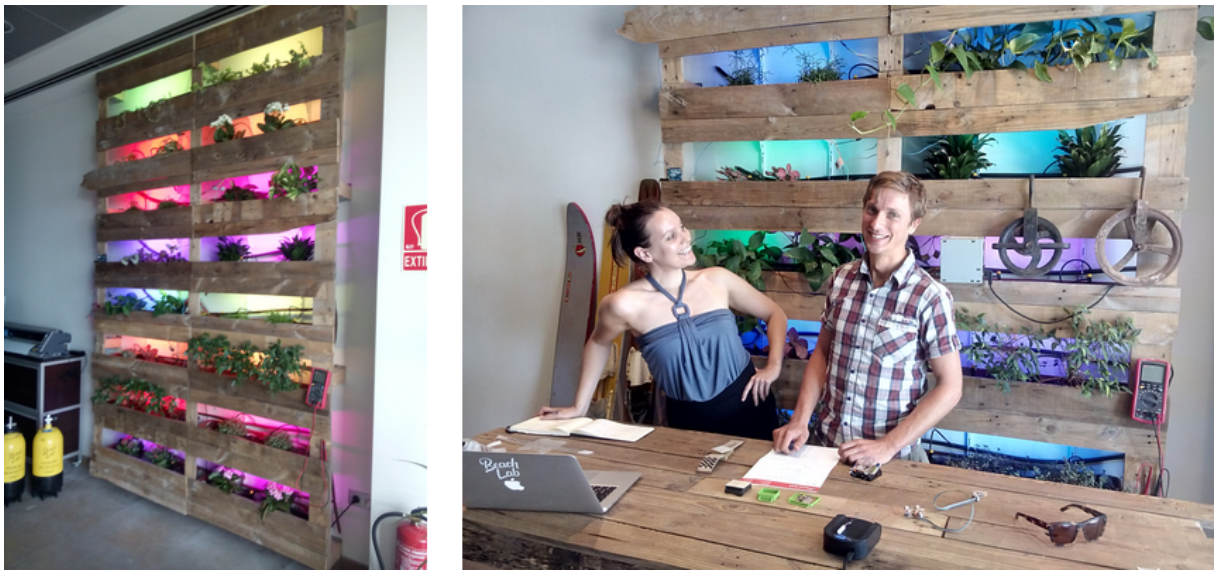


Figure 3: Pallet wood can be used to create amazing furniture and related workshops. In this picture *The Beach Lab* in Spain, showing a table and a vertical garden with embedded electronics that displays the amount of water in the soil using color codes.

3 Learning, making, sharing

3.1 The Sharing Space

The sharing space could be considered as a sort of mixer. It is, by far, the most important of the 3 spaces found in fab labs. If we fail to have a sharing space there will not be a community to build around. Ideally it is an open-access, informal space where people meet and gather together and interact. In most places it builds around food and drink, adopting the form of a maker cafe, or a shared kitchen. This space is suitable for all kind of interactions, and to showcase projects. And it is a relaxed environment for new members of the lab, who can enter and see what is happening inside the lab in a format that is friendly and known to them. We should avoid formalisms as corporate receptions which will not help in this kind of spaces.

Figure 4: Natural renewable materials like wood should be prioritized in the design of the fab lab. In this picture, a Shopbot machine has been used to design a custom organic shapes. In this kind of lab fabricated environments, it is easy to engage conversations and to explain the values of prototyping, design and collaborative assembly.

Figure 5: The sharing space is a great space to display projects developed in the fab lab. In this picture *The Beach Lab*. On the left a custom control panel for the lights of the fab lab. In the center a split flap display to display twitter messages. On the right a collaborative chalkboard where people can express their creativity. Some other spaces also have some kind of collaborative walls with lego parts that the members keep filling up. Or white sculptures that people draw with markers.

Drink+eat (kitchen) Soft seating Displays Showing: dashboards (visitors , indicators)

upcoming workshops upcoming events calendar tablets for workshop registration system Mini houses Phone booths Showcasing projects Interactive wall Creativity wall

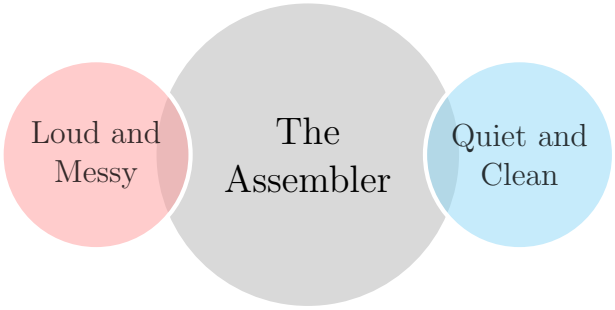
3.2 The Learning Space

The design of the Learning Space can be envisioned as hybrid classroom/lab. This flexible classlab blend elements of traditional classroom and laboratories to support the students working in several disciplines (biology, mechanics, electronics, etc.) at the same time. Students in these spaces typically work in groups of three, collaborating on real world science problems.

If space allows, it is recommended to dedicate a big central space as auditorium, where all the members can gather to attend lectures, guest speakers and perform big presentations and announcements. Otherwise, the Sharing Space is where this public activities also fit well.

3.3 The Making Space

The Making Space is the kernel of the fab lab, it's *where things happen*. This space usually host incompatible uses that make mandatory a division of the making space into 2 areas. The clean and quiet, and the loud and messy. If you can afford it you could organize the 2 areas around *The Assembler*, which is a central area with multipurpose tables to assemble and work in projects. The Assembler needs to be very versatile to be able to host very diverse projects, in terms of people participating and space and resources required. In this main area you could also have specificic shared design resources like a library of books/reading corner, multimedia production hardware for the creation and edition of audio and video content, VR technologies and 3D mouse for increased CAD productivity.



The Making Space is where you want to start thinking about access-control. It's not that you forbid or restrict who enters. It's that you should know who enters and whether they have the proper credentials and safety knowledge to operate the equipment. Because this is the area of the fab lab where potentially dangerous equipment is.

3.3.1 The clean and quiet

3.3.2 The loud and messy

3.4 Outdoors

Events Interviews Showcasing Chillout Bars Farm greenhouse Pavilions and structures Natural environment: Forest/desert/beach/sea/lakes/rivers

4 The Planning Process

4.1 Planning Phases

Phase 1: List the capabilities you would like to have in the Fab Lab. Elaborate your inventory according to your budget. This is a important step because you don't want to end up with duplicated equipment, missing equipment/materials, materials of doubtful utility and unbalanced number of machines.

Phase 2: Analyze the needs of these machines and their hosting spaces in terms of MEP (Mechanical, electrical,plumbing) and HSE (health, safety and environment). Determine which are the rooms that are more suitable for each type of machine.

Phase 3: Determine a layout plan for the separation of the spaces.

Phase 4: Elaborate a plan to implement furniture, MEP and HSE needs.

Phase 5: Develop and execute the chosen solution.

4.2 List of requirements to be assessed

For each of the above levels of assessment we will identify the following requirements:

Operational Logistics: How will the assets and people flow in, out and around? How will you manage the inventory (including maintenance, storage and locking requirements)? How will you control access? What's the maintenance plan? Is the facility ready for redundancy and resiliency when some equipment fail?

Mechanical, Electrical and Plumbing (MEP) requirements: Under this category it is included lighting requirements, HVAC systems, piping and plumbing, power and electrical requirements. Paying special attention to using the natural resources (natural lighting, natural ventilation, etc.) that can lower the environmental footprint of the facility.

Health, Safety and Environment (HSE): We should take very seriously Health, Safety and Environment aspects in Fab Labs. It's our social responsibility and our legacy to take care of the users, faculty and employees. The inventory of equipment, materials, workflows and processes that Fab Labs use and recommend have been carefully selected in order to comply with the highest standards of HSE. This also includes ergonomy and waste management.

4.3 Levels of assessment

When planning a Fab Lab, the above requirements should be assessed in 4 levels of detail:

- **The machine or process**. Each machine and process has its owns requirements.

- **The workflow around that machine or process**. A machine it's usually part of a bigger process or workflow, whose requirements you need to analyse too. If workflows are not identified, machines and materials will be placed randomly (incorrectly) placed without a logical arrangement. Ideally every machine and process should follow a logic workflow and have all its materials, inflows and outflows at reaching distance.
- **The room containing that workflow** must be analysed specially looking for incompatibilities regarding noise, dust, ventilation, etc. Not only Learning, making and sharing spaces should be separated. Within the making area of the lab, there should be separation of clean and quiet with loud and messy areas to avoid incompatible uses colliding.
- **The building containing that room** must be assessed as well. High frecuency vibrations created by digital fabrication machines can travel through the structure of the building causing trouble in areas very far areas from its origin.

5 Building the Lab

5.1 *Made in a Fab Lab* brand

5.2 Making your own Furniture

`http://opendesk.cc` Other designs Custom designs
Pallets. Reuse and upcycle

5.3 Giving the space modularity and flexibility

Furniture on wheels. Hanging AC power outlets Hanging exhaust

5.4 Other fabricatable items

3D printed and lasercut lamps
Alarm, CCTV, access control

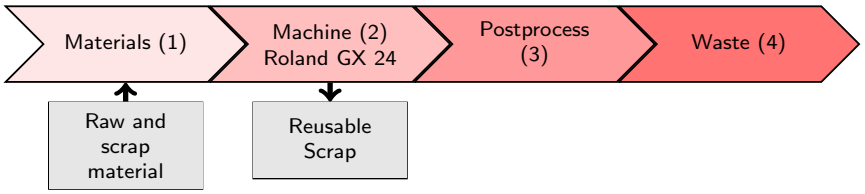
6 Processes and Workflows found in a Fab Lab

6.1 Table of processes

Process	Messy	Dust	Water	Noise	Lighting	Access Lock	Temp	Ventilation
3D Printing FDM	No	No	No	Moderate	No	No	Yes	Yes
3D Printing Resin	Yes	No	No	Low	No	No	No	Yes
Laser Cutting	No	No	No	Medium/High	No	No	No	Yes
CNC	Yes	Yes	No	High	No	Yes	No	Yes
Electronics Production	No	Yes	Yes	Moderate	Yes	No	No	Yes
Vinyl Cutting	No	No	No	Low	Yes	No	No	No
Industrial Robot Arm	Yes	Yes	Yes	Medium/High	No	Yes	No	Yes
Bio Lab	Yes	No	Yes	Low	Yes	Yes	Yes	Yes
Sewing Machines	No	No	No	Low	Yes	No	No	No
Molding and Casting	Yes	No	Yes	Moderate	No	No	No	Yes

Table 1: Table of processes

6.2 Vinyl Cutting



Notes

- (1) Additional items: X-acto, scissors, masking tape, vinyl gloves
- (2) This area requires also space for a computer for design and operation tasks. Provide enough power plugs (minimum 3)
- (2) The back of the machine must be reachable
- (2) Additional items: Tweezers, X-acto, scissors
- (3) This area requires the witdh of the biggest roll that the machine can handle and plenty of light
- (3) Additional items: Tweezers, X-acto, scissors
- (4) Waste: Paper backing, vinyl, Copper film, epoxy film.

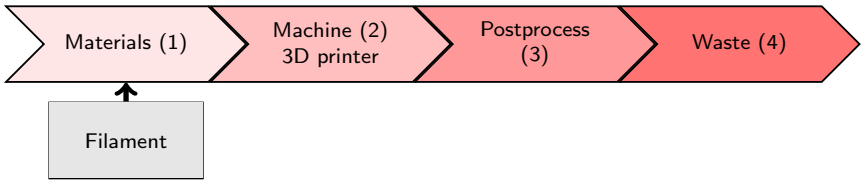
Risks

- Hand trapped by machine movement
- Cuts with sharp objects

Personal Protective Elements (PPE)

- None required

6.3 3D Printing FDS



Notes

- (1) Filaments require low moisture environment
- (3) Additional items: Wire cutter, spatula
- (2) Machine requires rear inspection
- (2) Power requirements: Most 3D printers don't require a computer. Newest require network connection.
- (2) HVAC direct airflow or low room temperature might affect buildplate adhesion and layer cooling
- (3) Additional items: X-acto, pliers, wire cutter
- (4) PLA and ABS based plastics

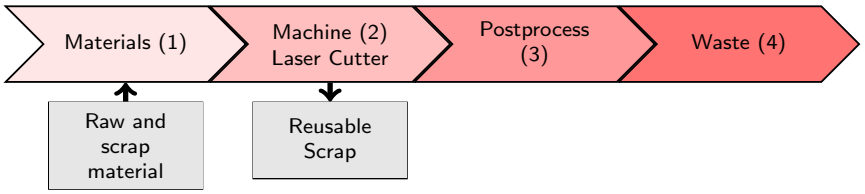
Risks

- Hand trapped by machine movement
- Burn by noozle or buildplate
- Hot plastic splatters caused by moisture inside filament

Personal Protective Elements (PPE)

- Eye protection is recommended for kids

6.4 Laser Cutting



Notes

- (1) Maintaining order of scrap material is important
- (1) Cardboard and wood are sensitive to moisture
- (2) The room requires ventilation and air renovation from exterior
- (2) The laser is usually a noisy environment, specially if there is also a filter installed
- (2) It is required also space for computer for design and operation of the laser
- (2) Power requirements: Provide at least 6 power plugs
- (3) Clean up scrap material and store it in (1)
- (4) Cardboard, wood, plastics

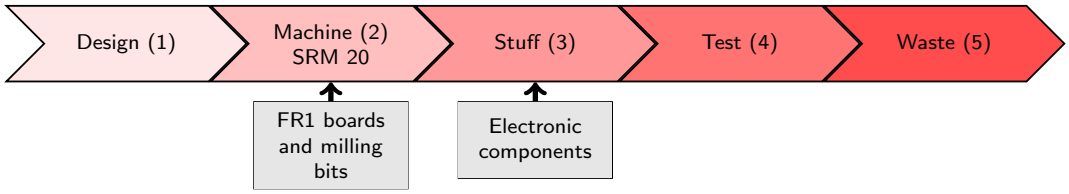
Risks

- Health issues due to long-term exposure to fumes
- Cuts by sharp edges of material

Personal Protective Elements (PPE)

- Recommended gloves for handling material and scrap

6.5 Electronics Production



Notes

- (1) Area for a computer next to the machine for design and machine operation. 3 power plugs
- (2) Additional items: Spatula, double-side tape, X-acto, Allen keys for milling bits, magnets
- (3) As this usually becomes a bottleneck of the process a minimum of 2 seats for soldering operators should be plannned
- (3) Easily accessible cabinets with electronic components
- (3) This area requires ventilation and air renovation, plenty of light and magnifying equipment
- (3) Power requirements for 2 seats: 6 plugs
- (4) 2 seats area for power supply, oscilloscope and function generator. Power requirements 6 plugs
- (5) Waste: Paper dust, FR1 boards, broken bits, electronic components

Risks

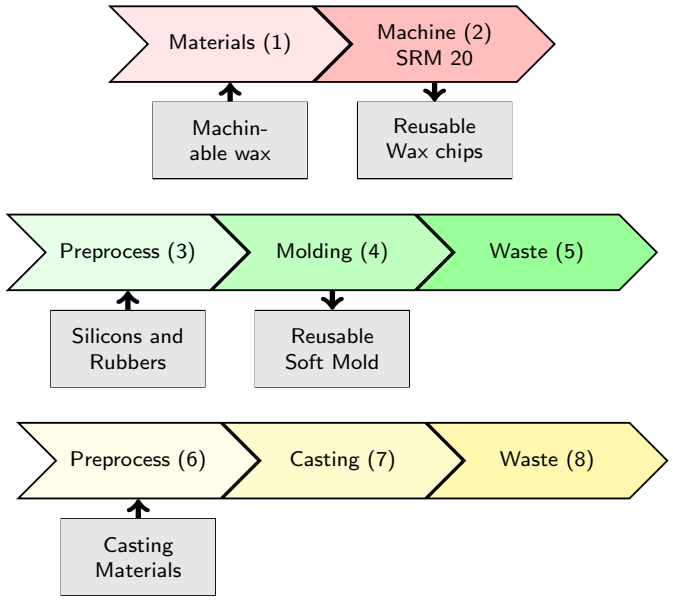
- Fumes inhalation
- Electric shock
- Cuts by sharp objects
- Burns by soldering iron

Personal Protective Elements (PPE)

- Gloves for removing boards and soldering
- Eye protection for soldering
- Isolating shoes

6.6 Molding and Casting

Molding and casting is a 3-phase process that can be done at different time and in separated rooms



Notes

- (1)(2) Phase 1 can be executed in the same room as electronics production. But it requires to clean and vacuum the machine and surrounding area prior to milling the wax. This phase produces virtually zero waste. A dedicated vacuum machine or a clean brush is recommended to pick up all the wax chips for future use.
- Phase 2 and Phase 3 can be executed in a separate room. These phases require a ventilated area and access to water and a sink.
- (3) Refer to MSDS for important health and safety information
- (4) Store reusable molds in the same storage room as silicons
- (5) Waste: Pots, gloves, sticks, etc, stained with silicons and rubbers
- (8) Waste: Pots, gloves, sticks, etc, stained with casting materials

Risks

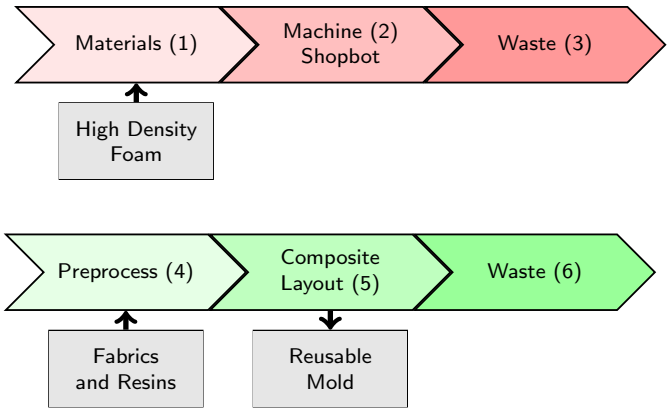
- Inhalation of dangerous volatile substances
- Eye, skin and lung irritation

Personal Protective Elements (PPE)

- Lab coat, vinyl gloves and eye protection during the molding and casting phases
- Masks and respirators upon the MSDS specs of the materials

6.7 Composites

Composites is a 2-phase process that can be done at different time and in separated rooms



Notes

- (2) Room containing the Shopbot is a very noisy, dusty and dangerous environment. Recommended separate room.
- (2) Room containing the Shopbot must have ventilation and filtration system. Refer to calculations in following sections.
- (3) Waste: Foam dust, high density foam
- (4) This phase requires a ventilated area and access to water and a sink
- (5) Store reusable molds in (1)
- (6) Waste: Sand paper and resin dust

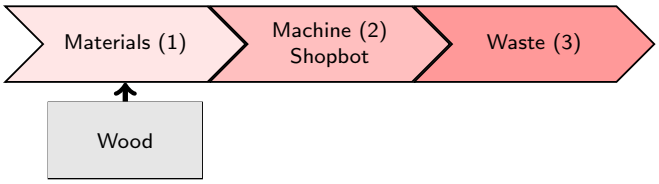
Risks

- Fine dust particles inhalation in milling phase
- Fast spinning cutting tool in milling phase
- Debris in milling phase
- Noise damage
- Being trapped by moving machine or spindle
- Eye, skin and lung irritation due to resins

Personal Protective Elements (PPE)

- Eye, ear protection
- Appropriate gloves for handling materials
- Coat, eye protection, gloves and mask/respirators during composite layout phase

6.8 Large CNC



Notes

- (2) Room containing the Shopbot is a very noisy, dusty and dangerous environment. Recommended separate room.
- (2) Room containing the Shopbot must have ventilation and filtration system. Refer to calculations in following sections.

Risks

- Fine dust particles inhalation in milling phase
- Fast spinning cutting tool in milling phase
- Debris in milling phase
- Being trapped by moving machine or spindle

Personal Protective Elements (PPE)

- Eye, ear protection
- Appropriate gloves for handling materials

Filtration System

Most of the time you are going to be working with wood materials. This equipment produces a loud and dusty environment. So, the first advice is placing all this equipment in a separated room. Most of these machines come with a dust collector that will capture the thicker wood particles. But still there will be finer cloud particles up to 10 micron that will not only float for around 30 minutes, but also will be suspended again with the slightest movement of air. The fine dust becomes a serious health issue. These fine particles will come from 2 sources. One is the dust collection felt bag that will allow particles up to 3 microns to escape through the fabric. And the second source is particles that because their high speed will never enter the dust collection system.

So I suggest that you install in these rooms a filtration system rated so that it will cycle through the entire volume of air in the room 6 to 8 times per hour. And with a timer for 2, 4, or 8 hours so that when the user will walk out of the room will flip the switch and forget about it.

7 Becoming a Super Lab

At some point your lab might naturally jump to the next level and provide the community with a unique space that becomes an international reference. In the network we call it a Super Fab Lab. A Super Fab Lab it's not just a lab with increased capabilities in terms of space and machinery. It is also attached to leaders with deep values and vision, there is much more planning and strategy involved and it is something that cannot be done in one go. You will need to correct and change things as the community reacts. Will your lab become one of the leading labs in the world, the ones that you can enumerate with just one hand, on par with labs of the level of Barcelona, Amsterdam and Boston? Let's see if you have what it takes.

7.1 The Champion

No half-measures here. Either you have it or not. As stated in Fab Foundation page, the Champion is a fundamental human resource for the success of the venture. It is someone who has the Fab Lab values, the passion for the job and a visionary goal for the future. If he/she is not within the founder team of the space, bad news ahead. It might take some time to find your Champion, or it might never show up. They might come from the faculty, students or members. My advice is to try to identify *The One* within your community. If it ever shows up, make sure you empower him to lead and drive the lab to the next level.

7.2 Team Diversity

One of the surprising things about fab labs is that the most beautiful and meaningful projects are never created by engineers. Engineers are weird people, and I can talk first hand here, while fundamental for their technical and organizational skills, need to be complemented by other kind of people. I recommend that you incorporate a broader set of people, skilled in arts, design and architecture to better attract, serve and guide the community in their projects.

8 Going Wireless, the Mobile Lab

9 What's next?