Whitepaper:
How to build a successful Field Lab

A guide for Field Lab initiators, partners and sponsors

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Box 1: What is a Field Lab? And what is not?

'Field Lab' is one of many terms to describe shared facilities on adaption and adoption of new technologies. Butter identified a 'wall of concepts' on such cooperations (Figure 1). We use 'Field Lab' as it combines Lab (adaption) and Field (adoption). Our observations apply to all concepts. A Field Lab must have (i) a physical location; (ii) focus on a new technology; (iii) multistakeholder collaboration; and (iv) open access.

(i) A Field Lab is a *physical location* with testing facilities, offices, meeting rooms and most importantly a coffee machine, canteen or other central meeting point that stimulates spontaneous meetings. This is essential to stimulate interaction, easy transfer of ideas, knowhow and expertise as well as spreading 'tacit knowledge': relevant information that well-informed and experienced people know, but is shared widely. This type of knowledge is essential to really understand the adoption challenges of a new technology and potential impact thereof. A cooperation without such a physical location is a project or program.

(ii) *The technology* on which the Field Lab focuses must be sufficiently developed to perform application tests, but not yet proven technology. It requires further development for applicability (speed and cost of production, efficiency, adaptability, user friendliness et cetera); proof of robustness and safety including long term impact; certification et cetera.
Proven technologies can be demonstrated in a Demo Lab. Even though specific applications may be developed in Demo Labs, these are commercially viable activities that do not need multistakeholder collaboration or (long term) governmental funding.

(iii) In a Field Lab, *multiple* (groups of) *stakeholders* collaborate. Potential users must be actively involved, as well as technology developers: universities, technology and research institutes and companies that aim to bring the new technology to the market. Often, educational institutes are involved. Governmental bodies may be involved as sponsor, potential user and developer of new legislation.
Cooperations with consumers or individual users (e.g. surgeons) are typically and preferably called 'Living Labs' and pose some separate challenges that are outside the scope of this paper.

(iv) Field Labs have '*open access'* for potential users. Preferably, the users have to pay for accessing the facilities and applying the knowhow of the Field Lab. However, there should not be overly strict rules or other barriers for participation. Governmental sponsoring is needed for the lifespan of the Field Lab to ensure that price is not too high a barrier, in particular for SMEs but also for midcaps.
If an initiative is not open to new potential users, it is a project or program. This may be as valuable as a Field Lab and is more easy to organize, but has less potential impact.

How to build a successful Field Lab

Field Labs [Box 1] can play an important part in transferring new technology to companies by bringing the ecosystem of technology developers and users together in joint projects, thus enabling technology adoption. But the reverse process may be as important: technology developers can learn a lot about the actual value and limitations of the new technology from the early tests by potential users. This will inspire adaption[1] of the new technology. To stimulate cooperation between developers and users, many 'Field Labs' or comparable initiatives are started with many different names (Fig. 1)[i] .

Figure 1: A family of titles for Field Labs, Butter 2017[i]

Building a Field Lab is time consuming, expensive and risky activity. This guide will help anyone who want build a successful Field Lab. It can also be used by potential partner and sponsors of a Field Lab. It is based upon research[ii iii iv v vi vii viii ix x xi xii xiii xiv] and personal experience[xv] of the authors. For a quick read, focus on the texts in black; details can be found in blue and smaller print.

This paper is financed by the EU-NSR Interreg project Exskallerate, which aims to stimulate the adoption of exoskeletons (Figure 2) in manufacturing and construction industries to improve health in workers that repeatedly have to lift heavy stuff. A Field Lab proves *not* to be the ideal solution for this specific case [Box 2].

Figure 2: An exoskeleton that supports the upper body reduces the load on shoulders and arms

Indeed, other ways to promote the adaption and adoption of technologies often are more effective than Field Labs. Thus, we arrive at the First Law for building a successful Field Lab.

1. **Be critical on the reasons to start a Field Lab and consider easier alternatives**

Why (and when) to build a Field Lab – and when not? Building a Field Lab is not easy. Before embarking on this endeavor, consider these four questions.

[1] Adaption and adaptation are both correct, interchangeable English terms. Although less frequently used, we prefer adaption as the twin sister of adoption.

Box 2: EXSKALLERATE

Exskallerate is one case where, in hindsight, Field Labs were not the best solution. This project aimed at adaption of exoskeletons, light weight 'suits' [figure 2] that reduce the muscular load on workers performing repeated (heavy) lifting tasks. Small Field Labs were organized in each country (Belgium, Denmark, Germany, the Netherlands, Scotland and Sweden) to demonstrate and test exoskeletons with SMEs in lifelike conditions. The Field Lab tests were useful: they delivered more than 15 separate improvements points to the suppliers of exoskeletons, adaption in full progress.

However, few SMEs were prepared to invest the time to travel to the Field Lab, which would often cost one or more days for one or more staff members, while the orders were stacking up at the production site. On the other hand, a visit of an expert to the production site was welcomed more easily. That also allowed *real life* testing and much longer testing, which yielded more detailed and relevant user experiences. These pilot sites proved to be a potentially viable paid service.

So in this case, an information failure was present. In addition, perceived risks include the business case and potential harm due to the exoskeletons. However, the infrastructure failure is only minimal (about 5000 euro per exoskeleton) and this infrastructure can be transported easily to the production sites. Therefore, pilot sites are to be preferred over a Field Lab.

Box 3: RAMLAB

'Stop palavering, start printing' was the title of the project started by Jacqueline Schardijn, InnovationQuarter. She noticed that the Dutch Maritime and Offshore Industry was interested in, but not working on, 3D-printing. Schardijn found sufficient companies willing to invest a small budget in a first test, to compare printing methods for the maritime industry. The project learned three things: (a) the WAAM-technology was the only technology with sufficient; (b) it wasn't good enough yet; (c) a sufficient number of regional users was interested.

Schardijn went on to set up a Field Lab. Vincent Wegener, a serial entrepreneur, was willing to start and manage it, and the Port of Rotterdam and the city of Rotterdam were able to support it with a starting budget. Hence the name: Rotterdam Added Manufacturing LAB, RAMLAB. Wegener built a closed group of technology suppliers (Valk Welding for the printing robot; Autodesk for the software; Lincoln Electric as welding experts; Air Products and the Linde Group for welding gases; Lemtech for safety; Element for materials). They invested in a joint large scale WAAM facility and a development program. Also, they set up a group of local users, that pay a subscription fee to stay informed on the developments and to join in demonstration projects.

RAMLAB demonstrated that WAAM is indeed capable of printing specific parts, often with significantly better materials properties and homogeneity than traditionally made metals. First systems are now sold by the technology consortium. The Field Lab went on to further develop the technology in several ways, e.g. on quality control and certification; on multi-material printing; and cobot technology and user friendliness. This is always done in joint development projects partly funded by EU, national and regional government and together with companies from all over Europe.

1A Do you expect to make sufficient impact for your stakeholders?

Is the potential impact of the new technology sufficiently large to validate the investments? Impact can be economic and societal.

Who is to benefit from the impact? Are they willing and able to pay? Are potential sponsors (local, regional and national governments, NGO's, banks) interested? Does it fit their policies? Do they have a budget available? When in doubt, consider starting with a cooperation with willing and able partners. If this leads to success and parties want to join the cooperation, a Field Lab may be developed from this starter project [Box 3].

1B Do you have sufficient regional base?

Is the *regional* base of expertise and the *regional* group of potential users sufficiently large to have a good starting position?

Boschma and Balland [xvi] demonstrate that regional development is most likely to succeed if technologies are selected that are closely related to the existing knowledge and skills base of that region. Is that the case, or are you building a technology castle in a desert? It often happens that a regional Field Lab, when established, expands (inter)nationally[v, vi], but only when the regional basis is a solid one and the Field Lab manager actively pursues this. A Field Lab that builds upon an existing network usually has an easier and less costly start[vii]. Also, a Field Lab that includes relevant partners in the value chain is more attractive to users[xii]. If the regional basis is too small, consider interregional cooperation or downscaling to a project.

1C Which market or transition failures do you address?

What problem must be solved. Q\What are the major and most urgent challenges in the adaption and adoption of the new technology that require action?

Why does the market fail in picking up the technology? We observe four major types of market failure[v, vi, viii]

- Information failure: potential users and technology developers have too little information on the opportunities the technology offers and its applicability and limitations, respectively.
- Perceived risk: insufficient objective, neutral evidence is available on robustness, safety, environmental and societal impacts, technologic and economic viability.
- Infrastructure failure: investments in assets, including test facilities, are too large for a single party, certainly considering the information failure and perceived risk
- Education or capability failure: current staff cannot work with the new technology and no education, training and/or skills development facilities and program is available (regionally)?

Transition failures [Dialogic, 2022] include network failure, in particular lack of new interactions and lack of growth of existing co-operations. A governmental failure is regulatory rigidity: current rules prohibit the use of new technology. Field Labs with local or temporary permits to test and demonstrate these technologies anyway can be highly successful [Box 4].

When three or more of these failures are obvious, including the infrastructure failure, a Field Lab is often viable. When no shared facilities are needed, build a project or program.

1D Is your idea unique?

Great minds think alike. If you come up with the idea for a Field Lab that is a *no-brainer*, it is *very likely* that someone else came up with the same idea [Box 5].

Try to find these other initiatives in all relevant networks and domains and aim cooperate. This may open up the possibility of actually starting a Field Lab, rather than dreaming about it [Box 5]. Often, it is worthwhile to join up with an existing Field Lab on a related technology, to share cost, reduce organizational hassle and to learn from experienced Field Lab builders [Box 6]. The sooner these find each other, the higher the probability they can cooperate. Regional governments, economic boards and economic development companies, have a responsibility in bringing relevant initiatives together.

Box 4: Green Village and Unmanned Valley

Green Village and Unmanned Valley both owe their success largely because they have exemptions for many rules and regulations. At Green Village, part of the TU Delft Campus, dozens of innovative ideas on sustainable building and renovation, future energy systems and climate adaptive cities have been tested in a lifelike environment where people live, work and learn. Knowledge- and educational institutions, entrepreneurs, government bodies and civilians research, experiment, validate and demonstrate their sustainable ideas.

Unmanned Valley, located at a former regional airfield (Katwijk), has ensured relaxed rules on the use of drones and no other air traffic on site. This is a unique facility in The Netherlands. At the site, drones can be developed, produced, tested and certified. An vocational school has recently started there. In future, Unmanned Valley hopes to get a permit for 'Beyond Visual Line of Sight' Flying, over the dunes to the North Sea. Such unique facilities attract (inter)national users.

Box 5: RoboHouse houses four initiatives

What do you do when you learn that four organisations independently want to start a demonstration site on robotics, but none of them has the power to make it happen. Obviously, you bring them together! In 2016, in a few months' time Anton Duisterwinkel learned that the TU Delft had plans for a demo- and testsite on robotics.. Also, the Delft based research institute TNO was leading a large EU-project on human-robotic interaction and needed to realize a site. The Applied University of The Hague needed additional facilities for their robotics courses and Festo, a company that delivers motion solutions, needed a new demo and education site.

After consulting each of the parties on the idea of cooperation, and getting positive feedback, I brought them all together and RoboHouse was born as a joint initiative, targeting mainly the manufacturing industry. Some companies, like ABB and Rabobank, soon joined. Meanwhile, RoboHouse has about 20 partners, has helped over 50 SMEs in deciding whether and what production step to robotize, has housed tens of student projects that work on challenges put by SMEs, has realized test facilities for diverse issues in retail, beer bottling et cetera.
RoboHouse is now transitioning into FRAIM, an institute where robotics in working environments are lifted to the next level. Robots are evolving from blind machines that need to be put in a cage for safety (Industry 3.0), via cobots that can work alongside people (Industry 4.0) into clever cognitive technology that complements and enhances humans, in all their diversity and complexity. Industry 5.0 which 'places the wellbeing of the worker at the centre of the production process and uses new technologies to provide prosperity beyond jobs and growth while respecting the production limits of the planet'. [https://ec.europa.eu/info/research-and-innovation/research-area/industrial-research-and-innovation/industry-50_en].

In our experience, many Field Lab ideas do no answer all four critical questions on the reasons for starting positively. Most Field Lab initiatives have more suitable alternatives and/or competitors close by. But even answering all four questions with a 'yes' does not guarantee success? What is success? Thus, we arrive at the Second Law of Field Lab building:

2. **Determine at an early stage what does 'success' look like for the Field Lab**

After establishing a group of early believers from all relevant stakeholders groups, start by defining the ambition/vision/mission/objectives of your Field Lab initiative.
To avoid abstract answers, rephrase the issue and ask: *when do we consider this Field Lab to be a success?* That helps to arrive at SMART objectives that are Specific, Measurable, Achievable, Relevant and Time-bound. This is a challenge in a multistakeholder cooperation on a new technology. Take your time. Consider these elements.

2A A solid understanding of each and all interests and leadership amongst the partners
Any cooperation is started not because partners have exactly the same objectives (if so, they should either consider a merger or face strong competition), but because they believe that their interests are sufficiently close.
In such cases, individual objectives may be reached faster and more efficient by cooperation. In order to find these alignments, as well as the points where individual interests differ too much to allow cooperation, each partner first must understand its own interests. What is success for them, both for your contact person and her/his managers? Make sure that you know who is in charge of this and therefore of the money [Box 7].
The next step is even more complex: partners must understand the interests of *all other partners*, as well as respect and value those interests. For the cooperation to become effective, partners must allow for and even help other partners to realise their interests. This is the basis for any potentially successful cooperation, even more so for a multistakeholder cooperation such as a Field Lab.
In addition, mutual trust between the partners must be build up. Also, each partner must be willing to invest, understanding that the benefits can become clear only after a while and may be different than expected. This requires leadership of one or more leading partners.

2B Setting multiple objectives
A Field Lab should have one ambition (e.g. doubling the adoption of exoskeletons in manufacturing industry in three years' time), but will have several objectives to serve all of its stakeholder groups (e.g. understand current limitations of exoskeletons; understand the business case for applications; reduction of muscular skeletal diseases in workers for government and for manufacturing companies et cetera).
Given 2A, each stakeholder must recognize its own interest in the objectives and endorse the other objectives.

2C Distinguish between results/outputs and impact/outcomes
It is important to define the impact or outcomes of a Field Lab, but also to realize that the actions of the field lab only lead to results or output. Define them separate and SMART.[xvii]
Field Lab ambition is defined at the level of impact or outcomes: e.g. what change or transition do we want to see in companies or in society. For instance, the adoption of exoskeletons by companies is such an impact. However, this relies on decisions made outside the Field Lab, in this case by a manufacturing company that must invest in exoskeletons, change its tasks and train its staff in the use of the exoskeleton. Such decisions may be influenced positively by activities in a Field Lab (demonstrations, field testing, calculation of the business case, trainings) but are also influenced by many other factors. For instance, economic uncertainty due to COVID and the war in Ukraine makes many entrepreneurs hesitant to invest in *any* new technology.

Box 6: More than 5..G

The Do IoT Field Lab stimulates the application of the latest IoT technology, at the moment of writing that is 5G. It is located at Green Village, Delft [Box 4] and active in diverse domains mobility, logistics, agriculture, health and safety and manufacturing. It offers, amongst others, mobile equipment to test 5G internet in green houses, production sites et cetera.

When the idea came up to set up a Field Lab on 5G in Dordrecht for maritime and manufacturing industry, at half an hour driving distance, we intervened and brought both parties together. Now, Do IoT has a satellite in Dordrecht as part of the Field Lab Duurzaamheidsfabriek, where industry and a vocational school work on sustainable technology projects. In addition, Do IoT has a satellite at Unmanned Valley [Box 4], as 5G is essential for 'beyond visual line of sight' flying.

Box 7: FreshTeq

Days before submitting a proposal for a subsidy, we got a nasty surprise. We had been building a Field Lab on digitalization of greenhouse horticulture, FreshTeq. A consortium was built around an existing demonstration center on greenhouse technology. The manager of that center was very enthusiastic and willing to finance his share. What we did not know and never had asked properly, is that not he, but his investor actually called the shots. This investor was not at all interested in the Field Lab and certainly not prepared to dish out any money. We could rent space, that was it. In one strike, we did not only loose a financing partner, but also the proposed manager.

Not prepared to throw away months' worth of work and with the deadline closing in, we quickly rearranged the finances and searched for another manager. A candidate emerged soon enough. A deal was struck, the proposal submitted, the subsidy won and the project started. Soon, it became apparent that the new manager regarded the subsidy as a project. A number of valuable project on vertical farming using LED-lighting, robot grippers, digitalization of water management and greenhouse design were executed to perfection. But a Field Lab could and would never be formed under this manager. We could have known that in time, but again, we never asked.

So, we learned the hard way to check. Check on who is actually in charge of finances. And check on the vision and ambition of the person actually in charge of the first project.

2D *Be flexible and be patient*

Promoting the adaption and adoption of a new technology typically is complex. So stakeholders need to be flexible, allowing the Field Lab management to 'fail fast', e.g. try out different strategies before hitting upon those that are effective. It takes time to build the organisation, the facilities, the courses et cetera, often a year or more. And even then, results build up slowly as not all potential users can or want to be served immediately. Impact takes even longer, as it depends on many other factors, decisions to be made and implemented. Therefore, stakeholders need to be patient. Governmental funding should extend over at least 4 and preferable 8 years, subject to intermittent assessments.

So, what are potentially successful adaption and adoption policies? Butter has answered this question in a slightly different approach, by defining a large number of potential services for the Field Lab and stating that (Butter's law, or the Third Law for Field Lab building):

3. **A Field Lab must offer multiple services**[xiii, vii]

A Field Lab is more than its facilities (building, research and test infrastructure, permits, software licenses et cetera). For those facilities to be useful, the Field Lab needs to provide *services* to companies – and it needs to be paid for those services.

Payment is not just needed for the Field Lab to be financially viable, but more importantly to ensure that it delivers *valuable* services. Free articles are is typically perceived as not very valuable. Moreover, if the SME is not able or willing to pay some fee for the services provided, why should we expect them to invest in the actual implementation? Finally, the need to find paying customers for services brings the urgency to the Field Lab organization that is required for success. But what services do the customers require?

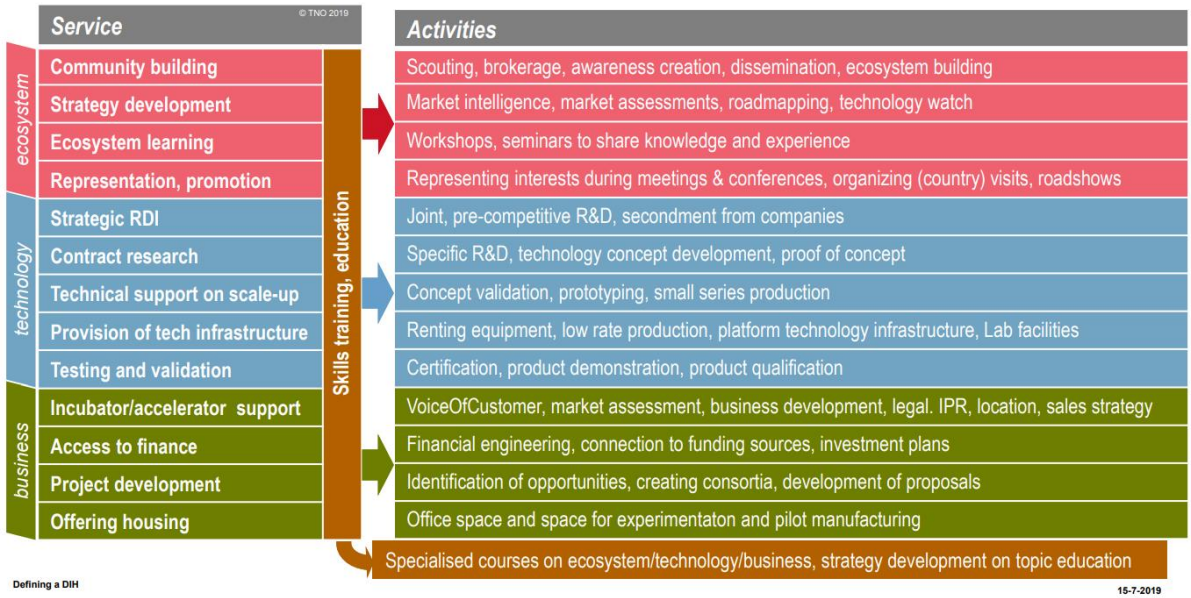


Figure 3: potential services that can be provided in innovation hubs (pink) that contain one or more Field Labs that offer technology services (blue) and incubators that offer business services (green), [Butter, 2019]

Box 8: SAM|XL

Manufacturing with large, thin sheets of materials, for instance in aviation, for wind turbines and ships, poses additional challenges in robotizing. The flexibility of the sheets makes it very hard to control the exact locations for gripping, drilling, cutting et cetera. For developing and testing suitable solutions, very large systems (gantry, robots) are needed and therefore large investments are required. TU Delft, TNO, Fokker (now GKN), Airbus DS, Suzlon and the SME's Airborne, KVE and GTM joined forces, aided by InnovationQuarter, and started the Field Lab SAM|XL (Smart Advanced manufacturing XL) to address these issues. The objective is low cost production of lightweight airplanes and ships (reduction of energy consumption) and wind turbines (clean energy production).

SAM|XL is highly successful, attracting dozens of partners, employing over 20 staff members and realizing development programs of tens of millions of euros in national and international programs. Its biggest challenge is and remains the funding of the large assets and everything that is needed to operate those: a large hall that needs heating and installations; safety systems; staff for operation, maintenance and safety; safety trainings; software licences, insurance et cetera. (Inter)national programs and users are willing to pay for the direct use of the facilities and the hours of experts involved in the project, and to a certain extend for basic software and its development, but less so or not for the basic facilities and staff mentioned above. As the facilities are big, so are the bills. Normal overhead rates just are not enough, and additional investments to accommodate for the growth are hard to find. This issue holds for most Field Labs, but the larger the facilities, the larger it becomes.

3A Develop several services

Butter[xii] lists a number of services that innovation initiatives can develop, depending on their objectives [Figure 3]. Stolwijk *et al* provide an extended list[v]. Field Labs are typically aimed at the technology oriented services, but may also include business oriented services if no suitable incubator is available. Also, they may offer ecosystem oriented services that Innovation Hubs (regional cooperation between innovation support partners) usually boost.

It is usually less obvious what the direct benefit of ecosystem services is to an SME, therefore paying for those services is not attractive for an SME[x]. Indeed, it is essential that the value added (what's in it for me) is clear to potential customers, and this value added must be based on customer needs. A Field Lab *may* offer Voice-of-Customer (VoC) services to its customers, but *must* use such an approach while developing its services. As many Field Labs initiatives are technology driven, that is frequently overlooked. Also, as in any commercial business, focus (developing one or a few services at the same time) and fail-fast (stop unsuccessful initiatives and adapt them or start anew) are important principles for developing successful services.

When it is clear which services your customers want and how they want it, it is time to think about your business model.

Do you want to work with subscription fees, are these equal for all parties, which perks do subscribers get? Do you want your customers to pay per service? How much, when and how, that is: in cash or in kind.

3B Consider developing educational services

In addition, a Field Lab may offer *educational* services on the new technology. If so, do ensure that one or more relevant private and/or public educational institutes are partners in the Field Lab. Building a quality course is an expertise in its own right.

Any new technology can be implemented only when managers see its value, designers understand how to get the most out of it, manufacturers know how to deploy it, and staff members have the skills to work with it. For this, a range of courses and trainings are required for the different user groups mentioned. Often, a deadlock occurs: individual companies feel the need for education but can't find suitable courses and (private and public) educational institutes see the need for such courses but can't find the students. A good way to break this deadlock is to find a *group of* companies that need the educational services, thus providing the first group of students. A Field Lab can play an active role in this.

An additional reason to involve students in a Field Lab is that companies find it attractive.

Field Labs can form an ideal platform to find talents[vii]. Also, students that find jobs at companies form a very efficient way of transferring knowledge and skills from the Field Lab to its users.

3C Do not shy away from servicing midcaps and large companies

Field Labs are often aimed at SMEs, and for good reasons.

SMEs create economic value, societal value and jobs. But adaption and adoption of new technologies is difficult for SMEs as they have few staff members that can manage those processes or have the technologic background needed. As technology development speeds up, these problems become more apparent and urgent. So, governmental bodies often finance Field Labs under the condition that they (only) serve SMEs. However, midcaps (with 250-1000 staff members) and large companies encounter comparable problems, certainly when they want to implement several technologies in parallel. Also, the cooperation between more agile and innovative SMEs and corporates with deeper pockets and international contacts is beneficial to both. Midcaps can play both roles. Finally, midcaps and corporates are more financially capable and stable customers to the Field Lab, requiring less acquisition effort.

Therefore, while a Field Lab may be aimed at SMEs, it must be open to all customers and may start with attracting larger ones. Also, the more the Field Lab leans towards *adaption* of the technology, the more important the contributions of larger companies becomes.

Another issue is that most SMEs will NOT be interested in Field Labs, because they innovate only when their clients force them to deploy well established technology.

Only the 'innovators' and part of the 'early adopters' in the technology adoption life cycle or Rogers' bell curve will be interested, certainly when the Field Labs focusses more on adaption than on adoption (Figure 4). Innovators constitute 2,5 percent of SMEs, early adopters in about 13,5 percent.

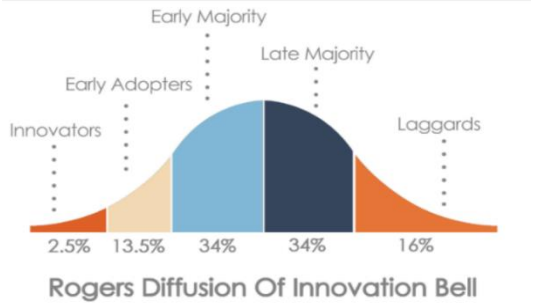


Figure 4: The technology adoption lifecycle shows that only a small part of SMEs is a potential user of a Field Lab, in particular the innovators and early adopters[xi]

3D Aim for public funding during the entire lifespan of a Field Lab

Field Lab are expensive[v]. For Field Labs to have a solid and quick start, it is essential that a sponsor invests in the early stage[vii].

Investments (CAPEX) are required in building, facilities, safety systems et cetera and operational costs (OPEX) are significant for *e.g.* staff, software licenses, materials, energy, insurance. When the Field Lab addresses market, system or transition failures, and fits regional strategies, regional public authorities often participate..

However, this is not enough. Maurits Butter, 2020, at a conference on Research and Innovation Infrastructures (RII, or Field Labs): "Normally, the RII business model requires a lot of public funding in the beginning, but within 5-7 years the share of public funding should decrease. However, for RIIs it is never going to be 0%."

A typical overview of the budgets required during the life span of a Field Labs and the relative public funding is given in Figure 5. Typically, public funding starts at 80 percent and slowly drops to 30 percent at the time of termination[x].

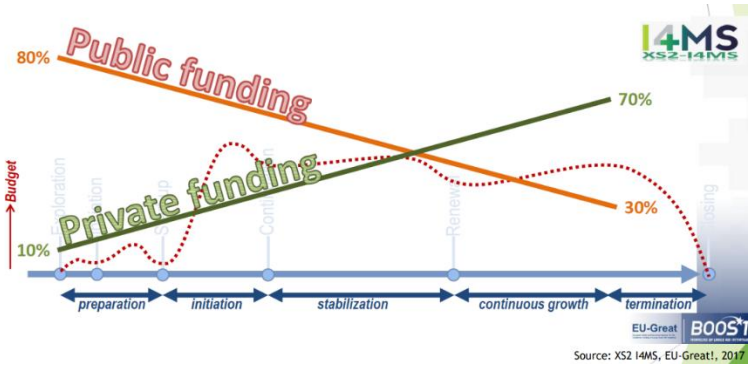


Figure 5: Typical budget and funding scheme for a Field Lab life span[x]

Companies take a significant risk when participating in a Field Lab, as it is unsure what the benefits will be. These are *potential* benefit*:* failure is possible. Therefore, companies must have the opportunity to bail out. This poses a significant risk to the financial stability of a Field Lab, warranting public funding.

The financial risks can be reduced through vouchers or subsidies. However, in most subsidies only costs are eligible that can be attributed directly to a project. Costs for the building, energy, safety measures, insurances, maintenance of facilities are not. Also, acquisition costs are not covered. Overhead rates in many subsidies are insufficient. This poses many Field Labs for problems. The larger the facilities, the bigger the problem [Box 8]. Moreover, companies typically prefer to pay '*in kind'* by allocating hours of staff or seconding experts to the Field Lab. This is the best way of ensuring technology transfer to the company. Cooperation between researchers and company experts also gives insights to both groups, and leads to new ideas and opportunities for innovation. *In kind* contribution should therefore be stimulated. However, a Field Lab cannot pay its bills with seconded staff: cash is necessary and should come from other stakeholders.

For these reasons, sustained public funding is needed. This should last for about ten years. By then, it must be clear whether and where application of the new technology is viable[v] and the major market, system and transition failures should be tackled. And this funding should be conditional. A public funded Field Lab must demonstrate the effectiveness of that public investments in the terms of 'success' as agreed upon by the partners.

Although being publicly funded in part, a Field Lab should be built and run as a business. However, a Field Lab always starts as a new organization and has only limited options for scaling up. Therefore, the fourth law of Field Lab building is:

4. A Field Lab is (and remains) a Startup and must be treated as such

A new Field Lab that is run like a business is a Startup. In many ways, however, Field Labs tend to remain Startups, because technology is developed rapidly, even within the Field Lab, and new customer (groups) are targeted continuously. A lot of know how is available on how to start a business. Paul Graham [2006] takes an interesting angle in describing which mistakes makes Startups *fail*[xviii]. The most important mistake, he states 'is not making something customers want' (cf Section 3A). But there's more to it than that.

4A You need a team – the best there is – and on the right tasks

A Field Lab needs to be as a company[vii], *i.e.* you need an entrepreneur that is committed to realise the Field Lab objectives. She (or he) needs a team with an expert on sales, marketing and communication (marcom); an expert on finance and administration and a technology expert.[2] You need a team! A team is also important *'to brainstorm with, to talk you out of stupid decisions, and to cheer you up when things go wrong'*, according to Graham.

The team members need to be committed and competent. Any Field Lab has a limited starter budget that is drained quickly in building, facilities and staff. As investors put it: you only have a limited runway before your money runs out. At the end of that runway, it's fly or die. So you better have the best pilot, the best sales person, the best ground staff and the best flight engineer you can get.

And you need them to do the most important things. It is very easy to get caught up with complex facilities and technological issues, not in the least because many Field Labs are technology push initiatives. But you need to focus hard on developing services that your customers want – because that's what the Field Lab is about. Often, only a small budget is set aside for marcom and even less for acquisition or sales. Sadly, this is enhanced because of the way many public funding schemes are set-up, inspired by way R&D projects are funded.

4B Be fast – but not too fast

Once you've established that companies are interested in the new technology you're promoting, you need to get a move on. Your potential customers are entrepreneurs who are (in)famous for having little patience, and rightfully so: their competitors don't have patience either. They are always on the lookout for fast and low cost alternatives. A (non-binding) Letter-of-Intent and a realistic time schedule on the development of the Field Lab and its services help to commit the entrepreneur, but offer no guarantees.

Three major sources of delay are (1) slow commitments of potential partners – you need to actively help your contacts in convincing their management; (2) lengthy procedures in public funding – so start early; (3) your own perfectionism: technology and services are never quite finished. A two pronged approach is needed: building good relations and pushing through. That sounds like a contradiction and indeed is a fine balancing act. Good relations with the potential partners, but also *between* potential partners, help to understand the root causes for hesitance or slowness. Thus, you learn what to do about the root causes and when you need to start using deadlines. Exactly the same applies for your staff members! Good relations with pubic authorities helps you to understand what they need to get approve your proposal, and get that first time right.

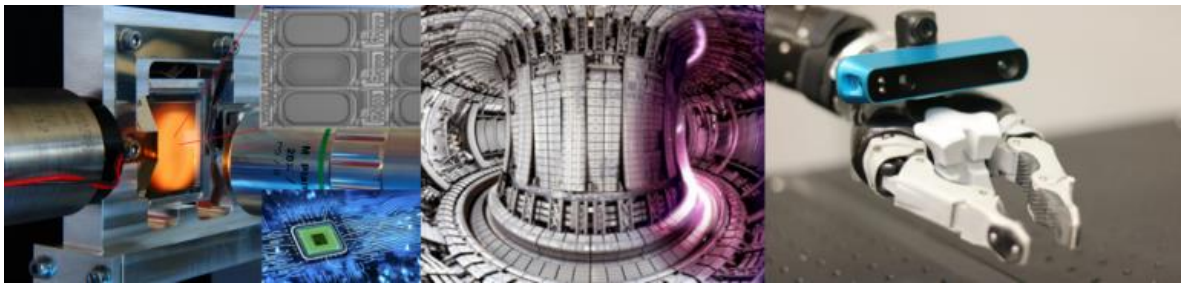
[2] More staff may be needed (legal, IP, safety, maintenance) but these do not form the core of the Field Lab.

Box 9: DOC

The Dutch Optics Centre in Delft, the Netherlands, is a long running cooperation between TU Delft and TNO. It aims at boosting the optics industry through joint R&D. It has been and still is successful in realizing R&D projects on developing optical and opto-mechanical systems for sectors such as manufacturing, semicon, agri-food, health, energy and environment with over 50 partners.

However, these remained individual projects, performed at different sites in TNO and TU Delft. A community is not or hardly formed, many project results cannot be published or shared and only very recently a first education project has started. We feel that as a Field Lab, DOC has never been able to grow to its full potential, mainly because the founding partners did not allow this to happen.

DOC is a valuable R&D cooperation of TNO and TU Delft with a large range of companies and R&D partners, delivering many interesting design and prototypes of optical and opto-mechanical systems. Had it been allowed to operate as an *independent* Field Lab, it could have had even bigger impact.



Vision-in-the-loop solutions developed by DOC in different project consortia

So, being too slow is bad, but being too fast is probably worse. Inviting potential customers at the opening of your 'Field Lab' while your facilities are not ready, your services are not in place and the business model still is unclear, equals suicide. You only can make a first impression only once, and this is certainly not the way to do it.

Often, your stakeholders, in particular the public ones and certainly when politicians are involved, pressure you to send out press releases and organize opening events. They have (finally!) invested in your Field Lab, and now everybody needs to know that. Do not cave in to that pressure. A good alternative is organize a *silent* opening for your stakeholders only. Celebrate the virtual start of your Field Lab, explain what you plan to do to get it up and running, provide a realistic time schedule and invite them to play a role in the *actual* opening. And then, get a move on in realizing all of this!

4C Manage your stakeholders

Managing your stakeholders is important at the start and throughout the lifetime of the Fieldlab. You need to be in the position that you decide, not the stakeholders. Build a governance structure with sufficient control AND independence. Be well prepared, clear, concise, respectful and open to suggestions and ideas, but also decisive. It may take some while, but typically you gain respect by doing so, certainly when your decisions pay off.

There are two reasons for this. First: you are the person in closest contact with the customers (at least, you should be) and therefore have the best information on what they need. Some investors and public authorities are more interested in what the world *should* look like, rather than what it actually does. Second: if public authorities or other large organizations are involved as stakeholder, you can get caught in lengthy, time consuming and defensive decision procedures of large organizations, and that's killing for a Startup. [Box 9]

Also, a Field Lab *must be industry driven, but should not be industry owned*.

If a single company owns the majority of the shares, its can decide at any moment to stop the operation, throwing away investments and input of all other stakeholders. Individual (larger) customers and customer groups should be involved in the governance, but cannot run the day-to-day operation of the Field Lab or decide on strategy on their own.

4D Get your hands dirty

Building a Field Lab is a hell of a lot of work, and a number of the things you need to do will not be in your comfort zone. Graham: 'If you're going to attract users, you'll probably have to get up from your computer and go find some. It's unpleasant work, but if you can make yourself do it you have a much greater chance of succeeding.'

He goes on to explain that in a bunch of startups he funded, there was only one that spend more than half of its time finding customers. That one was an order of magnitude more successful than all of the others.

Another thing that can make or break your Field Lab, is the IP strategy. Get experts in to help you out of this mine field. A very inspiring read is *The Innovation Matrix* by Mirjam Ros and Deepika Jeyakodi.

Finally, you need your financial administration to be up to scratch, certainly when using public funds. Again, experts are needed, but keep in mind that you are ultimately responsible and must be able to understand and explain the nitty gritty of your finances.

Box 10: Entrepreneurial exits

One of the potential exits, and in fact one of the possible aims of a Field Lab, is to realize an 'entrepreneurial exit'. In one shape or form, the activities of the Field Lab are commercialized. Three examples thereof include DFC, Smart Dairy Farm, SCSN.

DFC, Digital Factory for Composites was set-up in 2014 by Airborne and Siemens in The Hague to stimulate the digital manufacturing of layered composite materials. These are very strong and lightweight materials that can reduce energy consumption in airplanes, cars et cetera. However, as manufacturing was a manual job, the material was very expensive and could only be applied in very high end applications. Automation will cut cost and increase material quality. TNO, Sabic, and a range of SME's joined DFC, SMITZH and others funded the development and demonstration of the technology, e.g. using digital twins and automated tape layering. The aim of DFC was achieved around 2021 and the Field Lab was no longer needed. Now Airborne commercially offers the automation solutions together with its suppliers. In addition, TNO and a group of digitalization companies have set up a project to enhance digitalization in manufacturing SMEs by improving and expanding the use of data.

The Field Lab Smart Dairy Farming (2013, Drachten, The Netherlands), also was aimed at the use of data, but in this case in the production chain in the dairy farming sector. The data provide insight into milk production, the health of the animals and their reproduction and is used to optimize business processes. In 2017, the Field Lab partners started a cooperative datahub, together with a farmers organization (LTO Nederland) and a group of accountancy companies (EDI-Circle). This cooperation now aids farmers in using their data for improving their operation.

Smart Connected Supplier Network (SCSN) is a rapidly growing network of over 400 manufacturing companies and service providers on sharing data in the manufacturing production chain. By developing a standard for data exchange, this is made easy, fast and reliable. Data exchanged include orders, invoices, technical data et cetera. SCSN started as a Smart industry Field Lab that developed the standards and morphed into an non-for-profit association that promotes its use.

Box 11: Big Data InnovatieHub

The Big Data InnovatieHub (BDIH) in Zoetermeer, The Netherlands was started by the University of Applied Sciences The Hague and other partners at the Dutch Innovation Park in a former margarine factory in Zoetermeer. It aims at the improved use of data by SMEs in different application areas by helping to find business cases for Big Data or Artificial Intelligence applications. Originally, three application areas were addressed: (local) government, the medical sector and manufacturing.

When it became clear that manufacturing industry was hardly or not using the services of the BDIH, it stopped its services for this industry, while maintaining its activities for other sectors. It is now called Datalab and connect students and SMEs on Big Data and Artificial Intelligence. This is a typical example of the pivots a Field Lab can and often must make to ensure that it supplies valuable services to actual users.

Well, you've done all of the above and your Field Lab is flying. Be aware: a Field Lab cannot remain the same for a long period, as the technology is either successfully adopted, radically enhanced or changed, or aborted. Therefore, we find the fifth and final law for Field Labs:

5. **A Field Lab must *develop* an exit strategy**

After a number of years, when the first reliable conclusions can be drawn on the value of the technology your Field Labs boosts, it becomes time to think about its future. We tend to use the term *exit strategy*, which reflects the importance of this step more clearly. As the technology and the world in which you would want to apply it changes, it is essential to think about changing your organization. In practice, we have encountered the following 'exits'[v]:

- The Field Lab becomes a (not for profit) business, selling the technology commercially to users and requiring incidental project funding for further developments. Its name is or should be changed and its organization usually follows its changed function [Box 10]
- The Field Lab scales down to a project [Box 10]
- The Field Lab is terminated or ends certain activities [Box 11]
- The Field Lab develops into a next phase or pivots to a related technology [Box 5, 8]
- The Field Lab develops into or becomes part of a R&D organization
- The Field Lab becomes an education institute
- Any combination thereof [Box 10].

The decision to change or end a Field Lab has consequences for your staff, customers and stakeholders. Don't let this accidentally happen to them: involve them in the discussions and the decision, plan ahead and allow everyone to take the necessary steps in time.

Final words

So we hope that this paper helps you to build a successful Field Lab. It is not a recipe, as there are way more than 50 shades of Field Lab. Butter[viii] summarizes a number of aspects of Field Labs that each can be filled in different ways [Figure 6] – and can change during the life time of the Field Lab.

	Factor	
Full physical location	Location	Virtual network
Regional	Market focus	International
From research to some scale-up	Innovation focus	Pilot production, some research
Semi-open, after negotiation	Openness	Fully open
Industry driven	Governance	Research driven
Fully commercial	Financing	Long term public co-funding
Large companies	Target clients	SMEs
Legal entity	Institutionalization	Consortium of partners
Confidentiality	IPR	Own IPR and licencing

Figure 6: Aspects of Field Labs that you need to take a position in, potentially changing in time.[viii]

A single recipe cannot cover this, even a recipe book would not do. But we have tried to cover all relevant aspects and discuss the boundaries and do's and don'ts. Nevertheless, it can hardly be expected to be complete or perfect, as the science on innovation is also being developed. Please share your previous and current experiences with Field Labs of any sorts and your thoughts on shared innovation with us, so that we can further expand and improve this paper.

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