CERN IdeaSquare Journal of Experimental Innovation, 2017; 1(1): 42
DOI: https://doi.org/10.23726/cij.2017.523

IDEASQUARE COFFEE-PAPER

Towards enabling disruptive innovation in a diffuse funding and resources landscape

In addition to its main purpose of publishing experimental innovation research related results, CIJ also publishes more light, inspirational food-for-thought intended "IdeaSquare Coffee Papers". These pieces are collaborative efforts prepared by visiting researchers from various walks of life visiting or staying at CERN IdeaSquare premises. The identity of the contributing authors is kept anonymous (although known) but helpful hints can be found in the literature references. Editors of this section are Dr. Markus Nordberg and Dr. Valeria Brancolini.

EXECUTIVE SUMMARY

The purpose of this paper is to offer a "handbook at-a-glance" for enabling disruptive innovation in a diffuse geo-political and economic landscape. That is, to identify the enabling parameters for economy-revitalizing innovation in a geo-economically diffuse area. It is assumed that there are multiple parallel funding streams and resources allocation mechanisms, multiple political systems, diffuse legal and regulatory frameworks, and tight budgetary constraints and control. Our approach is inspired by systems biology and ecology-thinking. A five-step implementation plan is proposed, using research infrastructures as a co-innovation platform. An order of magnitude for required investments is given, as well as an expected multiplication factor over a time period of five years. We also offer a concrete example.

INTRODUCTION

Why this "Handbook"? In the spirit of the IdeaSquare Project[1], we experiment how to connect basic research mission with society-driven challenges in a new, mutually beneficial way, with the aim of scaling up the results. This involves our research community, the industry, expert innovation organizations, universities and alike to try out new things. Working together both with practitioners and academics, we use the unique opportunities offered by IdeaSquare also to carry out socio-economic studies and "out-of-the-box" intellectual exercises in the domain of innovation. We thus offer a short paper outlining a simplistic vision how the small scale and big scale could meet to boost innovation. It is intended to ignite fruitful thoughts and discussions in our regular Tuesday-morning coffee (croissants regularly offered free of charge as an incentive to turn up). Although our point of reference is obviously CERN – 22 funding European Member States in the domain of particle physics research with a global reach of over 11 000 registered users across the world – our scope is intended here to be wider and neither geographically nor scientifically bounded to the above. Our purpose is thus to remain general in our argumentation and conclusions, but restricting to an operational environment we are used to work in: many different countries, languages, best practises, experiences, different decision-making processes, different funding streams, different reporting experiences etc. As just one example, and used here as a guiding experience, is the way the large LHC physics experiments, CMS[2] and ATLAS[3], were set up and how they are currently run, each comprising over 3000 active scientists and engineers and being funded by over 40 countries each.

The current paper was triggered by the following question: how come you find so many resilient plants in the middle of a hot, dry desert? They seem to survive as a species, despite the scarcity of water, presence of storms and draught, and even deliberate efforts by humans to eradicate them. Or, what are the factors that make species survive under a fragmented habitat? For example when a road breaks a continuous land into patches? Bringing these questions to a higher level of abstraction, based on system biology[4] and ecology[5] thinking, we then asked this question: could innovation be used to create prosperity in areas of scarce resources but resilient actors?

So what is innovation? Just delivering an idea to market[6] ? Perhaps, perhaps not. Using Google search engine, one gets 407 million references. Billions are being made and (many more) invested each year in its name. It seems surprisingly little is known about it and what to do about it. Although the Library of Congress, for example, has 40 000 active references to published innovation-related material, it seems there are only a few things we *do* know: innovation appears to be a complex process (not linear), results often from a (random-like) trial-error process, takes often a long time

[1] http://www.cern.ch/ideasquare
[2] http://cms.web.cern.ch/
[3] http://atlas.ch/
[4] We were strongly inspired by e.g. https://global.oup.com/academic/product/the-origins-of-order-9780195079517?cc=ch&lang=en&
[5] See e.g. https://sites.google.com/site/joernfischerspage/habitat-fragmentation
[6] http://en.wikipedia.org/wiki/Innovation

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(decades rather than days), is very easy to destroy (days rather than decades), is open-ended (parallel, often serendipitous, opportunities-generating). It seems to involve persistent and often unmanageable or incomprehensible individuals[7], the original innovators seldom get rich themselves, and that it appears to be very difficult for both the governments and market-efficiency driven private sectors to steer or control it. What is also known is that innovation is one important engine or fuel of economic growth – but how big? 10%? 50%? 90%? And of what, exactly? Over what time span[8]?

In the current paper, innovation is considered loosely as a process with multiple deliverables or results, one of which at least is considered as useful by its customer or end-user. We assume this process can be complex, divergent at times, only seemingly (externally) manageable and can entail human drama. When successful, it adds value even if not always creating direct, pre-defined short-term economic value.

Our interest here is creating *breakthrough innovations*. For us, this means a sudden increase or a visible jump in knowledge or understanding of an important discovery that results from a series of longer term of trials (and errors) and which finds new use outside the original subject-domain. When successful, it creates new economic value with a measurable impact on society[9].

WHY BOTHER WITH INNOVATION?

Why then bother with innovation if it is so complex, fuzzy, seemingly stochastic (at least ex ante), and investment-intensive? Because history of innovation clearly demonstrates that it is an important catalyst of social change and longer-term prosperity[10]. The development of steam engines in the 18th century created the Industrial Revolution. The development of the telegraph and radio shaped the economies of the early 20th century. The development of the transistor triggered the Era of Electronics and paved the way for the Economy of the 21st century. Where did these inventions originate from? From scientific research that long preceded them.

Are we able to create theory-equivalents of Thermodynamics, Electromagnetism, Quantum Mechanics and alike? Yes, and we currently are: advances in mathematics, computing, physics, astronomy, life sciences and elsewhere are creating astonishing, new insights and knowledge how our Universe is constructed and how it evolves. New knowledge is out there and available to put in good use.

If so, how come it takes so long for the siblings of these fundamental discoveries to find their way to our living rooms? Because it takes time for new ideas and knowledge to diffuse. It takes time and resources for materials to improve their functional properties. It takes time and resources for different technologies to improve and become more compact. But more importantly, it takes time for people to change their habits. Thus, it is not only about technological perseverance but also about societal adaptation: things change when the ripe technology meets the ripe, receptive mind.

If this then is all about time, resources and social adaptation, can one reduce the innovation life cycle by connecting the end points somehow earlier and speeding up the process?

We have got ignition

The answer is: *yes*. Recent history has examples: The supersonic Concorde-project, the Apollo moon-missions, the Human Genome project. Although these examples were not basic science-driven, they heavily relied on a wide range of frontier scientific and technological advancements being made in parallel in other fields. But they certainly were not all economically driven, either, despite their optimistic projections.

The world has moved on and these days governments have much less of an appetite for contributing to audacious, risky BHAG-projects[11]. Yet we think this is where the problem lies: in an incremental, linear, low risk-taking and scattered system, regulated and diffused flow of funds hardly catalyse disruptive changes. Yet generating breakthrough innovations require that. More of BHAGs.

During the past decades, there has been a decisive shift by governments to pool their resources together to share risks, both technological and financial. In the field of science and technology there are several good examples of this. For example, in Europe, organizations such as ESO (Astronomy), ESA (Space research), EMBL (Molecular biology), ESRF (Synchrotron radiation), XFEL (laser spectroscopy), ESS (spallation source) and CERN (particle physics) have been created[12]. In the US, concerted research efforts have been made in astronomy (e.g. VLA project) and participation in international projects such as ITER (fusion energy) has increased. In addition to these international undertakings, many countries have their own, strong national laboratories which, in some cases, collaborate closely with their international counterparts and in other cases follow more closely domestic research policies set by their own governments[13].

[7] For a refreshing outlook on this aspect, see e.g. : http://books.simonandschuster.com/The-Innovators/Walter-Isaacson/9781476708690
[8] See e.g.: www.oecd.org/science/inno/39374789.pdf
[9] See e.g. http://www.abc-clio.com/Praeger/product.aspx?pc=D2776C
[10] See e.g. http://shop.nationalgeographic.com/1/1/75-national-geographic-concise-history-of-science-invention.html
[11] http://en.wikipedia.org/wiki/Big_Hairy_Audacious_Goal
[12] http://www.eiroforum.org/
[13] http://www.erf-aisbl.eu/

In Europe alone, there are over 350 research infrastructures or ERIs[14]. They, as their counterparts e.g. in the US, provide a wide range of scientific and technological expertise. Here, theory meets experimentation: research infrastructures are geared to design, construct and operate scientific instrumentation which is used to test and extend new theories. In many cases, their infrastructures are of industrial scale. The science they do is good, the technology they develop is good, the experts they employ are good – so how come web-like inventions appear so rarely? Our belief is that this is because as research infrastructures focus on their primary missions – as they are funded to do – they generate "innovation options" that are side products of the science process itself but that are systematically lost because there rarely is enough absorptive capacity outside the laboratories knowledgeable or capable of "calling" on these options[15]. Or, if it is there, it interacts in a random fashion. In order to reap these "options", one needs to co-facilitate the research mission of the laboratories with external, societal needs without compromising their research mission. In essence, it means bringing on board at an early stage external parties – and their resources – as equal shipmates or collaborators. They need to be on the same boat and share together the fame or shame.

Achtung, Baby!

We believe such a co-development mode is possible to achieve in a diffused funding and resources landscape. It requires, however, audacious use of scientific infrastructures such as ERIs in a new way. And like nursing a hedgehog, it requires careful handling and patience.

The idea is to co-align ambitious, scientific goals with societal absorptive capacity, and fuel it with the right mix of resources in order to create conditions of disruptive but sustainable lift-off. This requires defining a longer time horizon but reducing individual innovation life cycles within. This is achieved by applying the following guiding principles related to steering the process, generating options for new innovations, managing risks and balancing the required financial resources:

- Collaborate and compete
- Mix and inspire
- Absorb and reduce
- Roll in and roll out

Collaborate and compete

Many governments around the world, as well as parts of the private sector, have regarded the open, collaborative work spirit of the research community with some suspicion of hidden idealistic socialism. All of that changed abruptly in 2008, when Lehman Brothers, the bank "too big to fail", collapsed and by doing so created a global financial meltdown not seen since the 1930s[16]. The need for extending the collaborative (coordination) spirit into the private sector has been since recognized[17], while maintaining the competitive element[18]. This, in turn, has come as no surprise to the international research community that has since many decades worked in a symbiotic equilibrium of collaborating and competing, at the same time[19]. Research groups compete for latest results, for the resources and research positions, yet they form collaborations and share the research tasks – and the results. How can that be? This works when the research goals are ambitious (if not outright audacious), commonly recognized as important, well articulated and require pooling together resources. It may thus well happen that in one project a group of scientist collaborate, but in another – possibly even a parallel project – they compete against each other. Universities and research laboratories are well accustomed to this and are able to adjust their IPR-policies accordingly[20]. As a general principle, the next step should logically be "from open science to open innovation", a research agenda that is actively pursued by scholars like Prof. Henry Chesbrough[21].

The new insight is to engage industry from an early stage as equal collaborators or co-developers in the research projects. This requires adding an extra dimension in the goals-definition as the earning logics or "currencies" are different – for the researchers, it can be novel publications and scientific recognition whereas for industry it typically is profitability and growth. Thus, the goals need to include some element of agreed "divergence" which permits the research setting to optimise the creation of "innovation options" without hampering with the driving research mission. The key feature in this new relationship is that industry is also invited to contribute to the process of defining the research goals, having in mind some added functionality or performance which can be made available in parallel for industry.

[14] http://ec.europa.eu/research/infrastructures/index_en.cfm
[15] See e.g. http://www.discoverydrivengrowth.com/
[16] For a global analysis, see e.g. "The Financial Crisis Inquiry Report" by the US Government, 2011 (http://fcic.law.stanford.edu/report/)
[17] http://www.gauravbhalla.com/publications/collaboration-and-co-creation
[18] http://ukcatalogue.oup.com/product/9780199286034.do
[19] http://siepr.stanford.edu/publicationsprofile/2791
[20] Dealing with industry can, however, be a very different story. An example of easy IP access can be found here: http://www.gla.ac.uk/services/rsio/ipcommercialisation/easyaccessip/
[21] From Open Science to Open Innovation. Henry Chesbrough. Discussion paper, University of Berkeley/ESADE. 2014.

Mix and Inspire

Due to the longer-term research goal setting, obtaining conditions of continuity and sustainability requires engaging young researchers and students at an early stage. Again, there is nothing new in this for the research community. In fact, most research infrastructures specifically include in their mission statements the education of next-generation researchers and innovators. What is new here however, is to propose creating a more heterogeneous mix of scientists, industry, young researchers and students.

We suggest embedding cross-disciplinary MSc-student groups within the research teams who are given society/industry-driven project assignments which have, a priori, nothing to do with the actual research goals. Instead, these groups that consist of product design, business management and engineering students, start with end-user driven challenges[22]. These can include e.g. finding new product families, helping senior citizens more effectively cope with their daily routines, finding more efficient solutions for food preservation, improving energy efficiency of combustion engines, locating faster victims of natural disasters, or improving hospital patient treatment processes. The MSc-students are encouraged to explore possible technological solutions together with the younger researchers, while the more senior scientists are invited to assume the role of inspiring mentors (when applicable). In this manner, while the researchers can focus on their primary mission, they have at their disposal groups of students that can act as "option callers" and investigate the suitability of new ideas for other use, together with the industries involved. Several universities already offer such "design thinking" driven curriculum for the MSc- students and the results have been encouraging[23]. These courses include team building, entrepreneurship training and above all, heavy use of dedicated, rapid prototyping facilities where students work on their project assignments. The student teams are to design and construct together tangible prototypes, which are supported by a business case based on extensive feedback from identified potential user groups. PowerPoint presentations alone will not do.

We see evidence of challenging research settings inspire young students to solve society-driven challenges. There is evidence that if the conditions of engagement are right, the related teaching methodology offered by expert universities can actually create an "innovator's bug". Not all students will get the "bug", but there is indication that up to 50% of the prototypes built result in start-ups created by the students.

Absorb and reduce

When addressing the question of value creation and value capturing, these are in different parts of the phase space. Scientific research has the capability of creating value or "options". This is because the very objective of R&D is to reduce the original conditions of uncertainty, complexity or asset specificity. The R&D process transforms data into incomplete information and then, over time, to codified knowledge. Pure value capturing can start from this point, and the options space can then be narrowed down.

There are thus two very different mechanisms in place: scientific research is good at *absorbing* uncertainty or risks, whereas industry or markets are good at *reducing* it[24]. This difference is fundamental and not about semantics. To combine ambitious research goals with the intent of creating "options" for the market to capture requires completing the full loop between transformation (science) driven and transaction (market) driven incentives. This means that complementary type of funding is needed to minimize the associated risks: public funding for the absorption of longer-time risk and private funding for reducing shorter-term risk. Research infrastructures are a natural place to facilitate just that, as in most cases their research mission extends over many years, if not decades but while fulfilling their mission, they work together with industry to build the scientific and technical asset base.

Roll in and roll out

Last, but not least, the allocation and the timing of the different funding flows and resources require synchronization and coordination. That is, public and private funding needs to start and end at the right moment.

Most of the existing research infrastructure core missions are funded from Government sources. Obviously, this should not change. The scope of funding we are discussing in the current paper refers to complementary funding, where the basic infrastructure assets of research infrastructures for carrying out their mission are assumed as given. The complementary funding is rather targeted for specific projects which are *not* part of the baseline budgets of these organizations. These projects form an evolving platform of general purpose technologies (GPT) within which the flow of information is not restricted.

The selection and resourcing of the suitable partnership projects must be left to the community demonstrating clear ownership for fulfilling the project goals. That is, an agile governance structure incorporating the science, industry and innovation experts as equal partners and using well established, independent peer-review mechanisms. In this model, public funds are entrusted as a lump sum to a defined community or communities who takes the responsibility for the distribution, execution and reporting of its use. The research infrastructures do not decide thus on the funding, the

[22] https://hbr.org/2008/06/design-thinking
[23] See e.g. http://www.aaltodesignfactory.fi/
[24] http://collisionsandcollaboration.com/

communities *using* them do. This is in stark contrast to the current practise, where governments – with good intentions – bifurcate initially meaningful funding blocks into multi-staged and diffused small funding streams that have meanwhile lost their original potential of amplification or cross-pollination effects across different sectors of society.

The community/communities clusters around selected horizontal technology areas that have high cross-industrial or cross-societal *connectivity*. For example, one such community could focus on advanced, distributed computing. Another on strategic software aiming at creating an open access "Apple store" type of data or software depository as a basis for rapidly compiling and combining new functional product features.

While agreeing to the distribution and phasing of the public funding, the community/communities also need to facilitate the potential flow of private funds. This works when the Technology Readiness Level (TRL[25]) of projects has increased closer to market and where Time-to-Money becomes short. At this point, the Open Innovation policy needs to permit investors and related firms to leave the GPT platform, allowing them to home in on selected applications spinning out from the GPT projects. The partners may possibly even "close up" their interactions thereafter. This means that the partners who had joined the GPT platform core projects - where the initial, high risk had been absorbed using public funds – cannot make IPR claims to spinouts that leave the GPT projects. While leaving the platform, they make a small seed contribution towards launching the next round of "options creation" cycle.

In summary, the role of the public funding is therefore to roll in financial vehicles to permit initial, high risk taking and enable private funds to enter in and roll out projects that are closer to market. Then the process needs to repeat itself.

HOW TO IMPLEMENT IT?

We propose implementing the above guiding principles by using existing research infrastructures as general technology platforms; by focusing on domain-specific technologies that cut across several industry or society sectors; by involving from the beginning the science, industry and innovation experts as owners of the process; by organizing their work in a fashion that does not compromise their own primary missions; and by launching a pilot to test the scalability of the concept. This is implemented in five tightly connected parallel steps as follows.

Step 1: Use of research infrastructures

First, encourage the scientific communities using existing research infrastructures to share their research plans which involve development of next generation, ambitious scientific instrumentation. These are typically core projects related to building up new facilities or upgrading or significantly improving existing research tools. The life cycle of these projects can extend to decays. In Europe, for example, there are several: building a spallation source for material characterisation (ESS), constructing a powerful laser facility (XFEL), building new telescopes (ESO), building new beam lines and instrumentation for synchrotron light (ESRF), developing next generation sequencing (EMBL), upgrading particle physics accelerators and detectors (CERN) etc.

Together with the scientists and innovation experts, the technology development phases need to be written down and related performance parameters identified. Technological (not product) opportunities can then to be identified. Several mapping techniques exist to do this, for example by first identifying and mapping the related knowledge assets in a dynamical way[26].

Step 2: Focus on domain-specific technologies

Second, concentrate only on one or two well defined technology domains. Instead of leaving that entirely undetermined or unfiltered, focus on a technology domain that is at the heart of the selected range of scientific instrumentation but which, at the same time, has the potential of connecting to other technologies used in different industry or society sectors. An obvious example is ICT, which is a deeply embedded feature of basically any advanced scientific instrument and which touches in turn every imaginable sector of modern life. Scientific instruments in several domains need to generate massive amount of data and push the boundaries of ICT, e.g. in cloud computing. Another example is sensors and related electronics which are in the heart of scientific detectors used in physics, astronomy and life sciences, and which in turn can be found in a variety of automation and network technologies[27].

Step 3: Define ownership of the process

Third, define the communities that will be invited to join in as co-developers and who will own the process of creating "innovation options". The ownership of this process is thus not the same as that of capital investments made by the stakeholders of the research infrastructures.

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[25] http://www.publications.parliament.uk/pa/cm201011/cmselect/cmsctech/619/61913.htm
[26] https://hbr.org/2015/01/managing-your-mission-critical-knowledge
[27] http://www.frost.com/prod/servlet/press-release.pag?docid=277976956

The projects we are describing here are *not* part of the core projects of the research infrastructures, which are being funded from their baseline budgets. Instead, the projects we refer to are *supporting* them, with the purpose of creating "innovation options". Typically, such GTP platform projects are R&D projects that precede main investment projects covered by the research infrastructure budgets. Thus, they offer more flexibility in terms of engaging project partners outside the research domain and do not interfere with the primary mission of the research infrastructures.

Thus, coordinating and executing the GTP projects requires a dedicated governance structure. The stakeholders include: the scientific community, industry and innovation experts (e.g. investors, business angels, business schools and universities teaching innovation and entrepreneurship). The funding sources (public/private) are not part of the decision-making process.

Step 4: Define the roles of the partners

Fourth, clearly establish who will do what. The development and realization of next- generation scientific instrumentation is obviously the responsibility of the scientific community. That is, defining the scientific goals, functional specification and/or performance parameters.

The industry is expected to participate actively in the common R&D for the scientific instrumentation which is being done within the GTP projects. Industry is to offer new technological solutions, whenever applicable. In parallel, it investigates, with the help of the innovation experts, new technological or product opportunities arising from the R&D.

The task of the innovation experts is to help the industry to identify and materialize new business opportunities. This happens through advice from investment managers and dedicated MSc-level university programs which combine teams consisting of product design, business management and engineering students. These teams are embedded in the actual GTP projects and aligned with industry interests. Moreover, the innovation experts are to offer a range of services such as facilitating cross-linkages across the different GTP projects, to develop appropriate innovation indicators etc. The funding sources (public/private) need to agree at which point (TRL level) they switch roles: one exists as the other enters. As a starting point, we suggest setting the crossing point at TRL 4 whereafter IPR-questions become more problematic for an open environment to handle. While industry partners leave the GTP project(s), they are invited to make a small seed contribution towards preparing the next round of "options creation", i.e. preparing a new pilot or seeding project (see Step 5). Thus, over a number of iterations, the role of the public funding will become more passive. The most important point, however, is that the funding sources give the governance structure in charge of the GTP projects the flexibility to redistribute the funding and manage the entire process from defining calls, running the peer review process and selecting the projects for funding.

Step 5: Launch a pilot

Fifth, prototype it. Bringing together the scientific community, industry and innovation experts increases the connections exponentially, but also the complexity. It is better to start with a few projects to gain experience and trust, both between the different communities but also with the funding sources. The pilot should not be over-ambitious in reach. Instead, it should contain a mix of projects with different TRLs (and levels of risk) so that it can demonstrate the proof of concept in a couple of years. More importantly, the pilot must demonstrate scalability and that it can evolve into a self-sustainable model over a longer time frame. The pilot needs also to define meaningful impact metrics since neoclassical KPIs such as NPV do not capture, for example, the potential in "innovation options" or in cross-industry correlations.

The impact generated by using cross-disciplinary MSc-student groups needs also to be established and appropriate indicators need to be developed, possibly based on existing metrics[28].

HOW TO ASSESS THE INVESTMENT NEEDS AND THE IMPACT?

Our self-appointed (and worse, self-taught) arm chair economics team is in favour of options thinking while approaching a theory of disruptive innovation in a diffuse funding and resource landscape. Nevertheless, it rather narrow-mindedly believes that longer term prosperity and sustainable growth is based on producing tangible goods or assets that have value. This implies that the proposed investment in enhancing disruptive innovation has a fertile ground in that part of the economy that relates to manufacturing and production of goods. In terms of using the GDP of an industrialized nation as a basis of reference, this thus suggests we are looking as an order of magnitude, some 10% worth of the GDP[29]. Based on estimates that the share of advanced manufacturing (i.e. high tech) represents some 10% of the manufacturing sector[30] and that 10% of that is currently dealing directly or indirectly with research infrastructures[31], we conclude that the value of the described activity is within roughly one per mil of an industrialized nations' GDP (across all potential technology domains).

[28] See e.g. http://thegedi.org/research/gedi-index/
[29] http://stats.oecd.org/index.aspx?queryid=60702
[30] See e.g. http://www.conferenceboard.ca/hcp/details/innovation/high-medium-high-technology-manufacturing.aspx
[31] Estimated as share of suppliers to RIs per number of companies in the sector.

How much then to invest? This order of magnitude corresponds also to the annual budget of a major research infrastructure (in Europe). Assuming an average period of five years for the launched GTP projects and that more than five research infrastructures will be involved, we consider one per mil of GDP to be the an appropriate size (over five years) to create a measurable impact.

What is the multiplication factor? Research done on (secondary) economic benefits for industrial suppliers working with research infrastructures indicates a factor of three over a time period of five years or so[32]. As we are discussing here *co- innovation* rather than classical buyer-supplier relationships, we would expect the multiplication factor to be higher.

APPENDIX: ATTRACT AS A CASE EXAMPLE

The purpose of this Appendix is to briefly describe the need for disruptive innovation within the European landscape, using as an example the ATTRACT initiative[33] in the technology domain of detection and imaging.

Departing from tradition

The collaboration relationship between ERIs and industry in Europe has been largely moving in the perimeter of procurement especially for pan-European RIs[34]. Without denying the benefit of this trend, we believe that this type of relationship (suppliers/buyers) underexploits other available potential. In many cases industry serves ERIs with state-of-the-art technology that is enhanced or significantly modified in-house to achieve highly demanding purposes for extending the boundary of fundamental research. But it doesn't come back to industry. This may hamper the use of potentially breakthrough technologies in unforeseen market applications (as opposed to incremental improvements that industry excels). In other situations industry - although very interested in pushing its own boundaries - is solely guided on short term goals and large production volumes due to the need for immediate returns. As such, the challenging features and small volumes of the technology that ERIs require, stay out of interest.

ATTRACT proposes to depart from this traditional procurement relationship to involve ERIs and industry (especially SMEs) in early stages of technology generation (co-innovation). ATTRACT proposes to fully capture the *know-how* from ERIs and industry which is an element many times missing in a procurement relationship. This access to *know-how* and ERIs as technology test-beds is what incentivises industry to engage on high risk-high reward endeavours since it minimises the capital and resources for doing it entirely internally. For ERIs it provides also early-stage access to *know-how* related to manufacturing processes and integration coming from industry.

Connection with societal challenges and job creation

The ATTRACT initiative focuses on detection and imaging technologies due to four reasons. First, this is a technology domain directly connected with the interest and needs to expand the fundamental limits of science (therefore respecting the mission of ERIs). Second, it is an area in which many European industries (big or small) champion at the moment and where it is crucial to keep the competitive advantage (i.e. aeronautics, photonics, embedded systems, etc). Third, it constitutes a converging high tech paradigm directly creating market benefits (i.e. health care, air transport, biotechnology, etc) applied to society[35]. Fourth, as a high tech converging discipline it is well connected with job creation, job stability and job multiplication in Europe. In this context, statistics[36] show that of the more than 217 million workers employed in the EU-27 in the year 2011, about 10% were in high-tech positions. The creation of one high-tech job in a NUTS 2[37] region is associated with the creation of more than four additional jobs in the non-high tech segment of the same region. High-tech job growth was also more resilient during two recessionary periods—in the early-2000s and late-2000s. The focus of ATTRACT on detection and imaging technologies with wide docking points for ERIs-SMEs-Large firms, will certainly enhance the co-innovation potential that the initiative seeks.

Using the full potential of big and small industry in Europe through ERIs

Even in these times of crisis, statistics[38] show that across the EU28 in 2013, approximately 22 million SMEs in the nonfinancial business sector employed almost 90 million people and generated around € 3,7 trillion in value added. Expressed in another way, 99 out of every 100 businesses are SMEs, as are 2 in every 3 employees and 58 cents in

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[32] See e.g. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6448551&tag=1
[33] http://www.attract-eu.org
[34] For the case of CERN as an example http://www.oecd.org/sti/sci-tech/CERN-case-studies.pdf
[35] TechVision 2020 Program--Top 50 Technologies. Frost and Sullivan http://www.frost.com/sublib/display-report.do?id=D2BA-01-00-00-00
[36] Maarten Goos, Ian Hathaway, Jozef Konings and Marieke Vandeweyer, High-Technology Employment in the European Union, Discussion paper 41, 2013, KU Leuven VIVES (Vlaams Instituut vor Economie en Samenleving. http://feb.kuleuven.be/VIVES/publicaties/discussionpapers/discussion-papers-2013
[37] Regions eligible for aid from the Structural Funds have been classified at NUTS 2 level. http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction
[38] http://ec.europa.eu/enterprise/policies/sme/facts-figures-analysis/performance-review/files/supporting-documents/2014/annual-report-smes-2014_en.pdf

every Euro of value added. It would thus appear that SMEs are a highly parallelized machinery of value creation in a fragmented habitat like Europe. Statistics also show that high tech is among the five key economic sectors that account for approximately 78% of all SMEs in the EU28. In terms of the total value creation in the high tech sector (including knowledge intensive services) in 2013, the share of manufacturing SMEs involved was only 2%. In the case of large firms, the equivalent figure was 7%. However, the contribution of high-tech enterprises to added value is about twice as important. High tech SMEs generate roughly 6% of manufacturing value added while large high tech firms account for 13%.

The ATTRACT initiative proposes to enhance this total added value generated by the interplay of SMEs and large firms using ERIs. ERIs connect in many cases better with small firms which are more willing to engage in risky technological developments in exchange for finding a niche of a clear competitive advantage. They also benefit from the *know-how* and resources related to technology integration capabilities of ERIs. On the other hand small firms (specially micro and medium level) need quickly to find channels that large firms can offer to fully industrialize and exploit breakthrough technologies. ERIs as well can act in ATTRACT as “technology brokers” making large corporations aware of cutting edge technologies coming from SMEs.

BALANCING PUBLIC/PRIVATE FUNDING

In Europe, public funding is recognised as a driver for technological breakthroughs. Horizon 2020[39], as the biggest funding programme for EU Research and Innovation ever, offers the right financial platform for ATTRACT. It is not feasible to enter into a discussion on how the different principles and instruments of Horizon 2020 can be streamlined to ramp-up ATTRACT in this Appendix. Nevertheless, it is worthwhile to consider some general aspects. Besides funding *per se*, Horizon 2020 also carries a fundamental value of collaboration. This is very suitable for exploiting the untapped potential of ERIs-SMEs-Large corporations. Another crucial element that Horizon 2020 brings to the European scenery is continuity and stability for R&D funding.

These two factors are of crucial importance for ATTRACT since breakthrough innovation cannot be nurtured without them. They are also required to generate trust between ERIs-SMEs and large firms. Trust is essential for sharing openly information and knowledge needed for breakthrough innovation. In addition, Horizon 2020 can provide agile mechanisms for empowering the stakeholders of ATTRACT to fully define the goals at strategic and project level. It can also provide the mechanism for ATTRACT stakeholders to autonomously nominate independent bodies for evaluating the feasibility and impact of breakthrough technology, enabling to rapidly discard unsuitable cases based on evidence (using ERIs as test-beds). It is exactly this mechanism that can dock with the private sector since it inherently minimizes risks which are widely recognized to crucially hamper entrepreneurship in Europe.

ATTRACT will set up evaluation mechanisms for rapid screening and selection of technology opportunities tested in ERIs as a result of a co-innovation approach with industry. This will open the possibility to capitalise existing small firms or newly created ones with private resources. This balance between private/public can certainly have an impact in Europe since it is estimated that only 50% of European start-ups survive for the first five years[40]. It can also have an impact on value added helping to consolidate the SME-large corporation machinery by increasing the survival rate of smaller firms. While the number of micro companies in the European Union increased by 370,000 (2%) between 2008 and 2013, the number of small, medium and large companies registered no net growth, showing that SMEs face difficulties in scaling up[41].

Entrepreneurship and young entrepreneurs

Statistics[42] on entrepreneurship show that for 45% of Europeans it has never crossed their minds to start a business. The ATTRACT initiative will take on board the pilot experience by incorporating cross-disciplinary teams of MSc-students and multiply them across all running projects using the hosting capacity and experience of ERIs. The purpose of this is also to encourage the young generation to start an innovative company. Again the links between ERIs and SMEs will enhance this approach. Statistics also show that for 79% of Europeans it is difficult to start one’s own business due to lack of financial support[43]. The mechanisms outlined in the previous section leverage on public investment by using ERIs as test beds (risk reducing) and activate private financial mechanisms for entrepreneurship.

Recent studies show that Europe does not seem to lack capital, but there is a lack of appetite to invest in entrepreneurial ventures, partly due to a perception of low returns for investors. Indeed, from 1980 to 2012

[39] http://ec.europa.eu/programmes/horizon2020/
[40] http://ec.europa.eu/enterprise/policies/sme/facts-figures-analysis/performance-review/files/supporting-documents/2014/annual-report-smes-2014_en.pdf
[41] Same reference as above
[42] http://www.weforum.org/reports/enhancing-europes-competitiveness-fostering-innovation-driven-entrepreneurship-europe
[43] Same reference as above.

(including the years of the financial crisis), venture funds reported an average internal rate of return of only 1.3%[44]. It is interesting to notice a drop in private investment due to risk aversion, and a corresponding increase of government agencies acting as “venture capitalists”. As government agencies’ financing volumes are these days limited, this is exacerbating the challenge of accessing growth capital[45]. It is time for initiatives like ATTRACT to reverse these trends.

[44] http://www.weforum.org/reports/enhancing-europes-competitiveness-fostering-innovation-driven-entrepreneurship-europe and Eurostat statistics on EU companies by size segment http://ec.europa.eu/eurostat

[45] Salido, Sabás and Freixas (2013), The Accelerator and Incubator Ecosystem in Europe, Telefonica. Available at http://www.lisboncouncil.net/component/downloads/?id=897