COLLIDING DISCIPLINES

SCIENCE MEETS DESIGN FOR SUSTAINABILITY

CERN

Royal College of Art
Postgraduate Art and Design

Royal College of Art - Department of Service Design

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Summary

In 2017 the Royal College of Art partnered with CERN in an innovative project that brought together science, technology and design to propose solutions for international sustainability challenges.

The partnership between CERN and the RCA examined how innovative and disruptive technologies can help address the world's most intractable challenges by combining science with design.

The collaboration focused on addressing the UN's Sustainable Development Goals. These targets are the output of the largest consultation the UN has ever undertaken; over 8 million people were consulted, 70 countries were engaged in the working parties and 193 nations have signed up to them. The goals are a compelling and clear global articulation that seeks to bring about a world of prosperous and resilient economies, fair and just societies within the limits of what the world can provide.

The initiative brought together the world's leading scientists with the uniquely creative talent of the RCA. Together they've devised solutions that go far beyond what either party had expected and have truly demonstrated the power of interdisciplinary innovation. At the conclusion of the project the RCA hosted a symposium where the students presented the outcomes of these projects, which include applying CERN innovations to improve earthquake detection, tackling the issues of microplastics in the world's oceans and creating a more sustainable alternative to HFCs in air-conditioning.

The symposium, Future States: Science and Design for Sustainability, brought together industry, public sector and government to review not only the innovative outputs from the project, but also the new processes that it pioneered in interdisciplinary innovation.

The speakers at the symposium included the Head of innovation for CERN Markus Nordberg, who introduced the project along with Dr Nick de Leon, Head of Service Design at the RCA. Sir Brian Hoskins, Chairman of the Grantham Institute for Climate Change, discussed the important role that innovation plays in tackling Climate Change, Justin McGuirk, Chief Curator for the Design Museum, spoke about the capacity of design to drive change, and Alison Boyle, Keeper of Science Collections at the Science Museum presented a paper discussing social engagement with science. There were also papers on sustainability and design from Dean of the School of Design Professor Paul Anderson, Fellow of the Royal Academy of Engineering Professor John Wood and Dr Ronald Jones, Senior Service Design tutor at the RCA.

The approach taken used an action research methodology. RCA service design postgraduate students worked with teams of scientists and the Knowledge Transfer team from CERN both at CERN in Geneva and then back in London. The project involved

six distinct phases – Scoping, Orientation, Interchange, Ideation, Development and Dissemination. The approach used a service design methodology to develop systemic solutions that could address the systemic issues raised by the Sustainable Development Goals. They tested the ideas with experts both within CERN as well experts in each of the problem areas they had identified and also with potential users and other stakeholders. These were subsequently presented at a Symposium in London with a related exhibition. The audience at the symposium was drawn from industry, government, academia and the two project partners, CERN and the RCA. Both CERN and faculty from the RCA subsequently surveyed the participants of the project teams, and the organisers, for their perception of the experience. Their comments and the analysis of these as well as the observations made by the authors, is summarised at the end of the publication. The findings identified six key opportunities to improve the outcomes from interdisciplinary innovation, especially where science and design, technology and the humanities and social sciences come together:

1. *Managed Serendipity:* There is an appetite within the scientific community to see their scientific discoveries and technology innovations being applied to what might be referred to as "Grand Challenges", however too often this relies more on serendipity.
2. *Focusing and intensifying the "Radar":* Knowledge Transfer teams need to undertake a systematic review of major opportunities including the Grand Challenges, and intensify the "radar" to highlight emerging technologies that might just be over the horizon.
3. *Start with the problem:* A design led approach that starts by deconstructing the challenge, and understanding the needs and constraints of the key stakeholders. Starting with a technology and looking for a problem to fix tends to result in applying a distorting lens on the problem, that is then shaped by the possible solution.
4. *Mutual Understanding:* The importance of pre-briefing and orientation about the processes, ontologies and epistemologies of design and the science at the start is required to enhance mutual understanding and progress as a team.
5. *Spaces, Places and Visualisation of Ideas:* CERN's IdeaSquare space created an environment that was distinctly different from the rest of CERN and more conducive to the exploration of ideas and the generation of concepts in an uncritical manner. The RCA students' capacity to develop those ideas through visualisation, storytelling and prototyping so that the systems concepts could be understood in their entirety was crucial in generating confidence within the scientific community of the robustness of their ideas.
6. *Translating Ideas to Impact:* The process of dissemination is not yet fully complete, but the symposium enabled the ideas, concept solutions and innovation approach to be shared with interested parties beyond CERN and within academia and industry. As a next step it is important to share these outcomes with industry and governmental partners, and consideration might be given to creating a venture incubator and business accelerator as part of the KT function, where emergent concepts can be supported to a point where the private sector might be ready to invest, or partner in their development.

In the emergent “superscientific culture” long-range decision-making and its implementation become more difficult and more necessary. Judgment demands precise socio-technical models. Earlier the industrial state evolved by filling consumer needs on a piecemeal basis. The kind of product design that once produced “better living” precipitates vast crises in human ecology In the 1960s. A striking parallel exists between the “new” car of the automobile stylist and the syndrome of formalist invention in art, where “discoveries” are made through visual manipulation. Increasingly “products”-either in art or life-become irrelevant and a different set of needs arise: these revolve around such concerns as maintaining the biological livability of the earth, producing more accurate models of social interaction, understanding the growing symbiosis in man-machine relationships, establishing priorities for the usage and conservation of natural resources, and defining alternate patterns of education, productivity, and leisure. In the past our technologically-conceived artifacts structured living patterns. We are now in transition from an *object-oriented* to a *systems-oriented* culture. Here change emanates, not from *things*, but from the way *things are done*.

Jack Burnham, *System Esthetics*, 1968

Previous page: Mural depicting the ATLAS particle detector, , CERN, Geneva.

Wisdom vs Knowledge

"Fail Again. Fail Better"
Samuel Beckett, *Worstward Ho*, 1984

Nearly a decade ago, within the pages of the *New York Times*, Mark C. Taylor, a Professor at Columbia University in New York, wrote an article entitled, "End of the University as We Know It." In that article, Taylor's conclusions mirrored fundamental research carried out at the Harvard Business School, predicting that the future of *breakthrough* research and innovation would thrive within a single domain: *interdisciplinarity*. In effect, Taylor gave early voice to what by now, has become a truism: that research into shared *themes*, not disciplines, produces the most far reaching and therefore valuable innovations, whether in the arts or the sciences. The second of his six conclusions, as he imagined the future of the university, read:

> *Abolish permanent departments, even for undergraduate education, and create problem-focused programs. These constantly evolving programs would have sunset clauses, and every seven years each one should be evaluated and either abolished, continued or significantly changed. It is possible to imagine a broad range of topics around which such zones of inquiry could be organized: Mind, Body, Law, Information, Networks, Language, Space, Time, Media, Money, Life and Water.*

"Mind, Body, Law . . . " . . . themes, not disciplines. As prescient as was Taylor's forecasting the future of knowledge production, it remains true that educational and research institutions have been slow to wake to the fundamental and groundbreaking role interdisciplinary research will play within their futures. A number of the significant research studies echoing Taylor's article, not least, Lee Fleming's 2004 article for the Harvard *Business Review*, "Perfecting Cross-Pollination," repeatedly conclude that the *only time* we see "breakthrough innovation" is as the result of interdisciplinary research, rather than the holstered methods of monodisciplinary research. In time, new research methods have been fashioned, notably "postdisciplinarity methods," that helped to spawn institutions like MIT's Media Lab, which has evolved far enough to have inaugurated, in this year, an "Antidisciplinary Program." Nevertheless, it remains true that most universities and research institutions continue to linger in herds of stand-alone specialist-research silos, even if it is, by now, undeniably true that their research is ever less productive, and therefore less relevant, bobbing in the wake of cross-disciplinary research.

That said, irony stings because while "breakthrough innovations" result - *exclusively from interdisciplinary research* – interdisciplinarity itself fails as a method at rates far higher than earlier, more conventional research methods. At this moment in time, as interdisciplinary research methods evolve, and are perfected capitalizing on what experience there is at hand, these methods have undeniably become consumed, coping, as they must, with the ever escalating risk of failure. And yet there are examples, however rare, where the risks were mitigated, and as the result, breakthrough innovations produced, just as Fleming's research predicted. For example, Daniel Kahneman created a new discipline by integrating a hard science, economics, with a soft science, psychology, something exceedingly rare, to create a third hybrid-discipline, Psychological Economics, for which he won the Nobel Prize in 2002.

More irony. It too appears, from research by Fleming and others, that the farther apart the disciplines rest from one another, as in the case of economics and psychology, the greater the risk of failure with every attempt to merge them into an "interdiscipline." At the same time, where they do come together as a third discipline, just as in the case of Psychological Economics, their hybrid research results are consistently far more original, and as a consequence, impactful, possessing significantly richer value, than those stemming from monodisciplinary research. And so, you are left with an irresolvable dilemma: given everything we know, why wouldn't you attempt to create a new interdiscipline, merging at least two research disciplines, hard and soft, in order to address wicked problems in the greater world – even though the risk of failure is extraordinary. *Why wouldn't you?* In the end, it's simply a matter of the level of risk for failure that you can either manage, or stomach.

Substantiating the weight of my poignant conclusion about risk-taking, let me lean on the wisdom of a scholar, much younger than I, who, in a chapter titled "Fail Again, Fail Better," for Mary Jane Jacob's 2010 watershed book, *The Learning Mind*, wrote about interdisciplinarity:

> *It's a version of what Ronald Burt, a sociologist from the University of Chicago, calls the economy of borrowed ideas. "The usual image of creativity is that it's some sort of genetic gift, some heroic act," Burt said. "But creativity is an import-export game. It's not a creation game." Burt continued: "Tracing the origin of an idea is an interesting academic exercise, but it's largely irrelevant. The trick is, can you get an idea which is mundane and well known in one place to another place where people would get value out of it." At Raytheon, the military contractor, Burt asked managers to offer up their best ideas about improving business operations, and the ones with the most value consistently came from managers who were already working operationally across disciplines. They were aware of new information and methods for problem solving that existed beyond their sphere of influence, and then adapted them to their own working group. "People who live in the intersection of social worlds," Burt wrote in the American Journal of Sociology, "are at higher risk of having good ideas."*

What you have just read is, indeed, a passage from my chapter, "Fail Again, Fail Better," I wrote for *The Learning Mind*, and in my experience, these decade-old thoughts continue to ring true, just as the risk of failure in interdisciplinary research remains steep. The real message here is that the enhancement of interdisciplinary research methods has been no more than incremental over the last decade, and if failure rates remain high, so too does it remain true that, just as Burt wrote, "People who live in the intersection of social worlds, are at higher risk of having good ideas." This underscores that breakthrough ideas continue to come *exclusively* from interdisciplinary research, which, in turn, had no small role in originally opening the door onto the collaborative work being carried out between The European Organization for Nuclear Research (CERN), and the Service Design Department of the Royal College of Art (RCA).

The collaboration between CERN and the RCA is an ambitious effort to simultaneously address and advance research aspirations shared by the two institutions. Inspired to work alongside one another by the United Nations' Sustainable Development Goals, the joint results are impressive, but could it be, taking the long view, that the fresh interdisciplinary research methods which percolated up as scientist and designer worked alongside one another, will have more far-reaching value than the results of any individual collaboration between them? I think so, for both scientists and designers.

A key premise of the collaborative work, which took place in Geneva at CERN and was then followed up at the RCA in London, was itself nested in a vital research question: why does the mainstream design world so rarely converge with the sciences in fashioning attainable solutions to the world's wicked problems? The reason for this cultural divergence, while explicit, is *paradoxical*, and why? Because on the one hand, there is the record of consistent failures that result from interdisciplinary research, especially when, like science and design, the disciplines are traditionally practiced at great distances from one another. Let's return to Lee Fleming's research. Fleming looked at 17,000 patents of all sorts – from medicine to business to design – and his research suggests, and I quote: "that the . . . value of . . . innovations resulting from such cross-pollination is lower, on average, than the value of those that come out of more conventional siloed approaches." But, he continues, "my research also suggests that breakthroughs that do arise from such multi-disciplinary work, though extremely rare, are frequently of unusually high value— superior to the best innovations achieved by conventional approaches."

In short, while there are many more success stories employing conventional monodisciplinary methods in research, we only see breakthrough innovations, of the highest value, produced by interdisciplinary research. To put it resolutely, whether in the sciences or the arts, we presently lack sufficient imagination to conceive of another methodology – other than interdisciplinary hybrids – capable of producing such a high level of creativity. Asked by a friend the other day to explain this collaboration between CERN and the RCA, I told her, "Well, we always had the knowledge, but now both scientists and designers have the wisdom too."

Ronald Jones, PhD
Senior Tutor
Royal College of Art

Introduction

In this paper we explore the nature of interdisciplinary innovation, describe the way this has been applied in the CERN – RCA experiment and then examine the results of this collaborative effort. We describe not only the project outcomes that demonstrate the inventiveness of the CERN/RCA teams, but also the new knowledge and processes that can be applied to future innovation projects.

In 2017 CERN collaborated with the Royal College of Art, London to explore how an interdisciplinary approach to innovation that combines science, technology, design and business might generate new thinking and potential solutions for the UN's Sustainable Development Goals.

The reason for focusing on the UN's Sustainable Development Goals is that these are the output of the largest consultation the UN has ever undertaken. Over 8 million people were consulted, 70 countries were engaged in the working parties and 193 nations have signed up to them. The goals include agreed targets and are a compelling and clear global articulation of what we need to change to bring about a world of prosperous and resilient economies, fair and just societies, within the limits of what the world can provide.

The RCA - CERN experiment in interdisciplinary innovation involved postgraduate students and faculty from the RCA's Service Design programme supported by senior faculty and teams of scientists from CERN, and was facilitated by CERN's Knowledge Transfer Team.

Interdisciplinary Innovation and the Role of Design

For more than 50 years designers and scientists have compared and sometimes combined their contrasting epistemologies, and despite a few collisions, can demonstrate that such an interdisciplinary approach can help address some of the more intractable and complex problems.

Buckminster Fuller (1965) used the term 'the "Design Sciences" decade' for that period in the sixties when innovators from different disciplines sought to combine sciences, technology and rationalism to address complex social and environmental problems. As Herbert Simon emphasised, the purpose of this collaboration was not only to create scientific knowledge of products or engineering components and their interfaces (Simon 1969), but also to systematise the design process and develop rigorous design methods, led byBruce Archer at the Royal College of Art's (RCA) Design Research Unit (1968).

We can trace back the importance of an interdisciplinary approach to design, to Simon (1969), in his call for design to create common ground across the arts, technology and sciences (1969), and in his suggestion that designers must deal with the unpredictability of human aspects, which requires designers to work within an ever evolving system.

The pioneering work by Archer, along with the leadership of Professor Sir Misha Black, led ultimately to the founding of a double degree course at the RCA combining Industrial Design with Engineering and creating a new programme: Innovation Design Engineering (IDE). The programme has now been in existence for almost 40 years and alongside it, an even more interdisciplinary programme of Service Design has been established that combines systems engineering, design, computer science and business. The IDE programme has resulted in the creation of dozens of new business ventures that have been incubated at the RCA and made the RCA the most successful university for generating new and thriving businesses. Similarly the RCA's Service Design programme, that these students were drawn from, has developed an unprecedented number of industry and government partnerships seeking to exploit an interdisciplinary approach to challenging issues in health, education and the criminal justice system, as well as in financial and retail services, and in the transformation of the automotive industry to a mobility services one.

However, bringing together the very best resources in their specific disciplines does not assure success —in fact the success rate of interdisciplinary innovation is traditionally poor. There is a record of consistent failures especially when the disciplines are practiced at great distances from one another. In an article published in the *Harvard Business Review*, Lee Fleming's research shows that it is true that the most common outcome of interdisciplinary research is failure (2004). Fleming looked at 17,000 patents of all sorts

– from medicine to business to design – and his research suggests, and I quote: "that the ... value of ... innovations resulting from such cross-pollination is lower, on average, than the value of those that come out of more conventional silo'ed approaches." But, he continues, "my research also suggests that breakthroughs that do arise from such multi-disciplinary work, though extremely rare, are frequently of unusually high value—superior to the best innovations achieved by conventional approaches." So we are faced with a conundrum: when interdisciplinary approaches are used, failure is more likely, but when it succeeds, then the value is far greater than that achieved through conventional approaches.

If this is the case, we might ask how we might mitigate the risks of failure so as to achieve the exceptional gains illustrated by Fleming's analysis. In the 1990s the term Design Thinking emerged (Buchanan 1992), and was later developed through the early 2000s (Brown, 2009) not only for innovation in products and services, but also to address business, organisational and management challenges. Design Thinking is defined by Brown (2018) as '*a human-centred approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success.*'

Design Thinking demands an interdisciplinary approach to innovation and with it, provides a structured approach to problem solving that offers tools and techniques which have been successfully applied in both the public as well as the private sector to address complex social and commercial challenges and opportunities.

It is this approach that the teams used to mitigate the traditional challenges of interdisciplinary innovation outlined here. The scope and complexity of the issues addressed by UN's SDGs cannot be resolved solely by technological innovation or by design, societal or economic interventions. It will require a systemic approach to innovation that exploits all of these.

Design Thinking as an Integrative Discipline

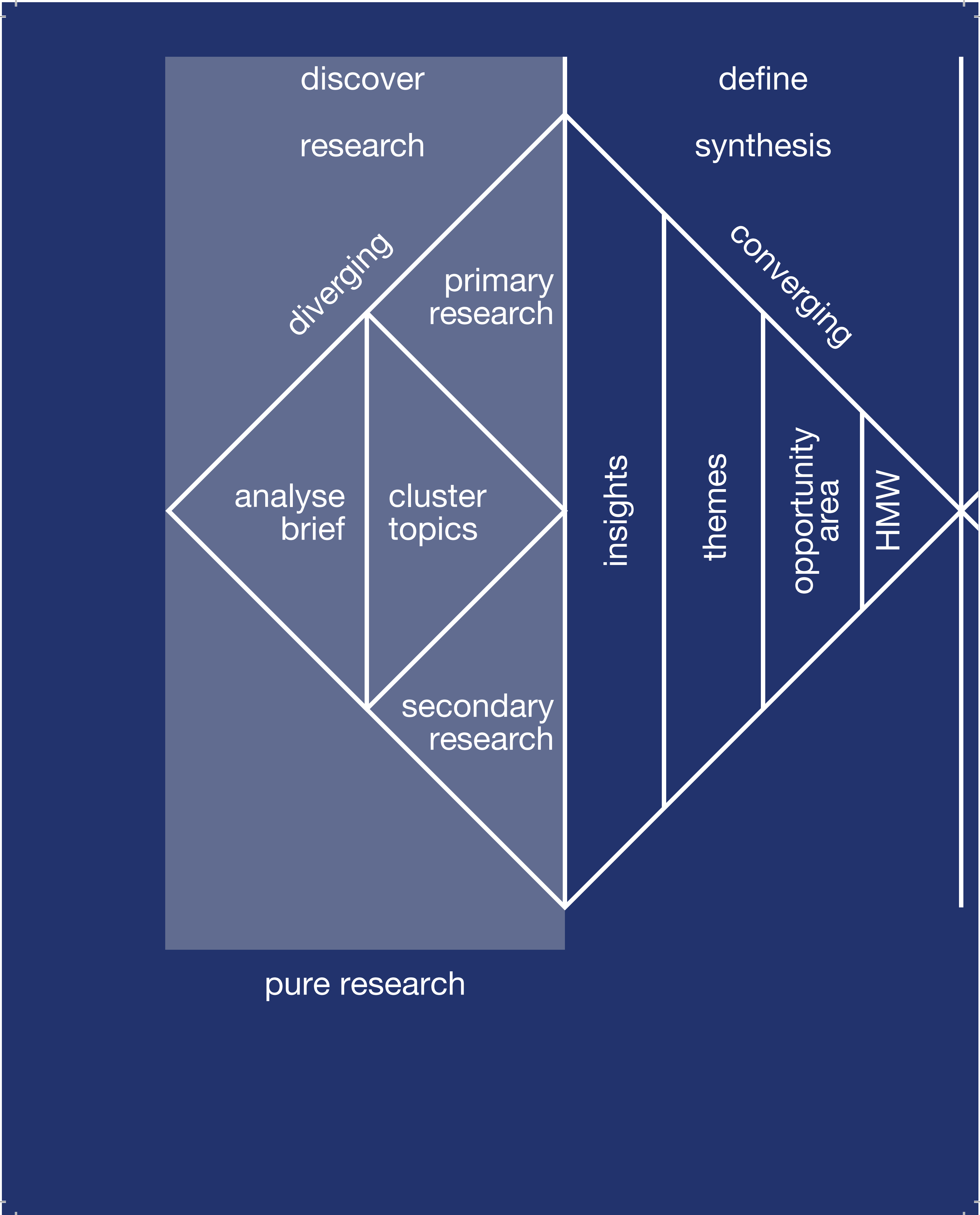
Design Thinking has become a tool not only for product innovation, but also for the development of business strategy (R Martin, 2009). It has also led to new approaches for service innovation (Spohrer and Maglio, 2008), and organizational and management innovation (Gruber and de Leon, 2015), and has even been successful in the emergent field of design for policy (Junginger, 2014; Bason, 2014).

As a result of the success of this approach in policy and public services, there has been a recent trend for government to set up or sponsor innovation laboratories that use Design Thinking as a means of not only developing new services but also formulating policy, creating new policy instruments and contributing to government strategy. These laboratories include Policy Lab, which is part of the UK Cabinet Office, MindLab in Denmark, GobLab (Laborotorio Gobierno) in Chile and others at both city and regional level. (NESTA, 2012)

The emergence of these centres for policy and service innovation is in recognition that a different approach is needed to tackle the innovation imperative both for policy and services (OECD, 2014). Recent literature argues that linear models of policy making, public administration and service delivery cannot cope either with the 'wicked problems' of a complex world or with the increasing demand and expectations of citizens (Colander & Kupers, 2014; Muir & Parker, 2014), so this alternative approach has to come from "beyond policy" — opening the boundaries of traditional epistemologies for public policy making and public service delivery.

These policy laboratories and their trans-disciplinary design practice, draw upon the work of Daniel Kahneman Nobel Lauriat, 2002, and his pioneering work on the psychology of judgement and behavioural economics. Burns et al. (2006) suggest that designers are well placed to help solve complex social issues, leading to changes in the way public services are delivered.

It is in this context that CERN and the RCA developed this experiment whose objectives were to test how an interdisciplinary innovation approach that combines two very different epistemologies, cultures and methods could be put into practice. It also sought to examine whether the results of the experiment could provide not only some new directions in terms of potential solutions to the SDGs, but also in terms of developing new approaches to innovation.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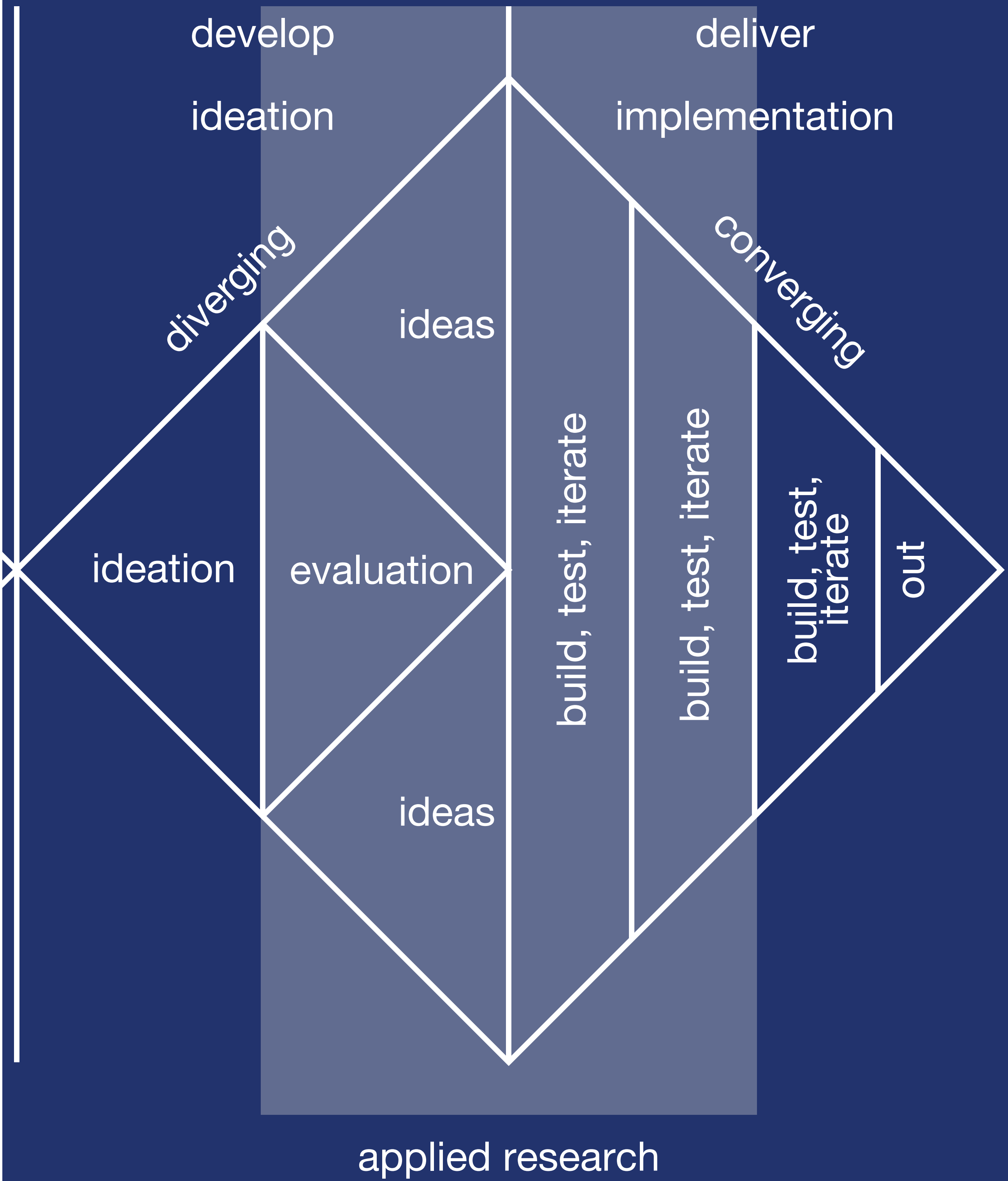
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Research Approach

The approach taken used an action research methodology involving teams of service design postgraduate students from the Royal College of Art, who were drawn themselves from a variety of disciplines. They worked with teams of scientists and the Knowledge Transfer team from CERN. The solutions they developed were subsequently presented at a Symposium in London with a related exhibition. The audience at the symposium was drawn from industry, government, academia and the two project partners, CERN and the RCA. Both CERN and faculty from the RCA subsequently surveyed the participants of the project teams, and the organisers, to record their perceptions of the experience. Their comments and the analysis of these, as well as the observations made by the authors, is summarised at the end.

The project was undertaken in six distinct phases: Scoping, Orientation, Interchange, Ideation, Development and Dissemination.

1. Scoping

The initial scoping was undertaken by senior members of faculty from the RCA and the Executive team at IdeaSquare at CERN. The goal of this phase was to identify which of the scientific innovations that had emerged from CERN, including current areas of interest as well as recent applications of CERN technology by CERN's Knowledge Transfer team, might be relevant in terms of their maturity, comprehensibility, and utility for applications that could contribute (and the emphasis is on 'could',) to the UN SDGs. A set of technologies was selected by the combined team who then organised the team and briefed the participants on the project structure and provided a relatively open ended brief to encourage the designers' creative contribution.

2. Orientation

The Orientation phase involved setting up interdisciplinary teams from within the RCA drawing upon a cohort of postgraduate design students that come from a wide range of backgrounds – from computer science to philosophy, from product design to psychology. 17 designers were selected and each was assigned one of the 17 UN Sustainable Development Goals on the basis of their personal interest, previous work or project activities undertaken at the RCA and skill base. They were asked to explore the nature, underlying causes, UN targets and national and international initiatives to address their assigned SDG. Similarly, the scientists and Knowledge Transfer Team at CERN were informed about the project, briefed on Design Thinking and asked to prepare to provide a briefing for the designers on their scientific and technological domain and the scientific innovations that could play a role in this initiative. The following areas were selected for initial investigation: Cryogenics, Sensor Technology, Hyper-vacuums, Gas and Particle Detection, Robotics, Data Science and AI, Spectroscopy. The goals of the project were documented in a shared brief, that identified how the designers and scientists would work together and specifying the objectives and principle deliverables from this shared initiative.

3. Interchange

The designers visited CERN and after a first day visiting the principal experiments and control rooms at CERN and the Large Hadron Collider and Anti-Matter Factory, they were introduced to the cafeteria at CERN and asked to mingle and socialise with scientists at CERN, explaining their project and exploring the roles and areas of expertise of the scientists they met. The goal of this activity was to enable the serendipitous exchange of knowledge and interest, collisions not of particles but of ideas, of different creative cultures, and develop potential sources of inspiration for the designers.

The designers were then briefed each morning on one or more of the scientific and technological domains, and then in the afternoon they explored how each of the SDGs could benefit from the technology they had just heard about. This process was repeated throughout the week and by the end of the week, from the matrix of technologies and SDGs, the designers were asked to present back to the RCA faculty and CERN team:

- Their first reflections on the SDGs they wished to focus on
- The technologies they believe could contribute
- Their initial ideas on how those technologies might be applied in the form of a product service system proposal

4. Ideation Phase

The design students then returned to the UK and used Design Thinking (T Brown, 2009), and specifically a service design approach, to reflect on what they had learned, research further the SDGs and then examine the target users and communities that would benefit. This involved researching their actual needs and the environmental, economic, socio-cultural or political context in which any solution might be constrained. The designers were asked to create different levels of prototypes from visualisation and storyboarding, simulation and modelling through to operational prototypes. They were asked to test the concepts that emerged both with the scientists they had met as well as with the target communities or at least people who were expert in those domains, and to iterate based on the input they received. The individual teams were mentored by two representatives from CERN, Prof John Wood and Dr Markus Nordberg, and interacted with the scientists and UK experts from academia, government and industry to refine their ideas. The process they used was in 4 stages: i) explore the human, societal and environmental aspects of their domain, ii) develop key insights and define the opportunity, challenges and constraints associated with that domain, iii) generate systemic concepts that could address that opportunity and prototype, test, refine or pivot and select a proposition to explore more deeply, iv) develop a detailed proposition including consideration not only of its potential impact but also a high level business model that could demonstrate its potential economic sustainability.

The specific actions they undertook in this phase were specified as follows in the project brief:

- Carry out desk research to understand SDGs and identify opportunities for product service systems that could create a transformational opportunity to a known and well defined challenge
- Identify a particular area where you or a

member of your team may have specific knowledge, experience from previous projects or links to organisations that could be relevant to one or more of these domains
- Visit to CERN for briefing by KT Group and then work with CERN KT Group and Idea Square as well as other stakeholders to understand how these new and disruptive technologies could make an impact on one or more of the SDGs
- Identify key stakeholders who help or hinder sustainable development entrepreneurial ventures, in the public, private or third sector on their journey from ideas to impact
- Map out the existing challenges including people's lives affected by these sustainable development issues as well as the organisations trying to address them. And identify the problems, challenges and opportunities that exist for and within these environments.
- Use co-design workshops to identify opportunities for design interventions either by tackling the existing experience or creating a new design approach.
- Use feedback from these sessions to develop a greater degree of specification than your earlier projects, validating your design solutions with key stakeholders.

5. Development Phase

Following the initial concept development, students visited CERN once more, and with this input they revised their solutions before presenting their final proposition to a combined group of faculty from the RCA, scientists and members of the Knowledge Transfer Team from CERN. The activities performed by the designers in this phase were as follows:

- Design a product service system that is highly granular so that it can be delivered by an organisation and show how it would benefit not only the recipients of the service or product service system but also the organisation delivering that solution
- Build a functional prototype for all or one specific part of the product service system and visualise/describe the rest of it.
- Test your design proposition with users, before documenting the service with a detailed blueprint and a viable deployment plan.
- Describe a business model that demonstrates that the service could be commercially feasible, either through return on investment or return on social capital.

6. Dissemination

In order to disseminate the outcome of this collaboration, the RCA and CERN ran a symposium, *Future States*, which brought together industry, public sector and government to review not only the innovative outputs from the project, but also the new processes that it pioneered in interdisciplinary innovation.

At the symposium the designers presented the outcomes of these projects which include applying CERN innovations to improve earthquake detection, tackle the issues of microplastics in the world's oceans and create a more sustainable alternative to HFCs in air-conditioning

The speakers at the symposium included the Head of Innovation for CERN Markus Nordberg, who introduced the project along with Dr Nick de Leon, Head of Service Design at the RCA. Sir Brian Hoskins, Chairman of the Grantham Institute for Climate Change, discussed the important role that innovation plays in tackling climate change, Justin McGuirk, Chief Curator for the Design Museum, spoke about the capacity of design to drive change, and Alison Boyle, Keeper of Science Collections at the Science Museum presented a paper discussing social engagement with science. There were also papers on sustainability and design from Dean of the RCA's School of Design Professor Paul Anderson, Fellow of the Royal Academy of Engineering Professor John Wood and Dr Ronald Jones, Senior Service Design Tutor at the RCA.

All of the solutions were exhibited at the Royal College of Art, and over 5 days the exhibition was visited by over 1000 members of the public. Over 150 representatives from academia, government, scientific and cultural institutions and industry attended the full day symposium and the presentations presented that day. Alongside the exhibition and symposium, details of the propositions were shared publicly and have been downloaded hundreds of times within the first months following the symposium.

Project Outcomes

CERN

Royal College of Art
Postgraduate Art and Design

Agri+

Xiaoyi Hu, Yu-Ting Huang

Agri+ is a system service that operates on soil sensors and knowledge transfer networks, connecting small scale farmers with supply chain and supporting them to make more actionable and wiser decisions.

2 ZERO HUNGER

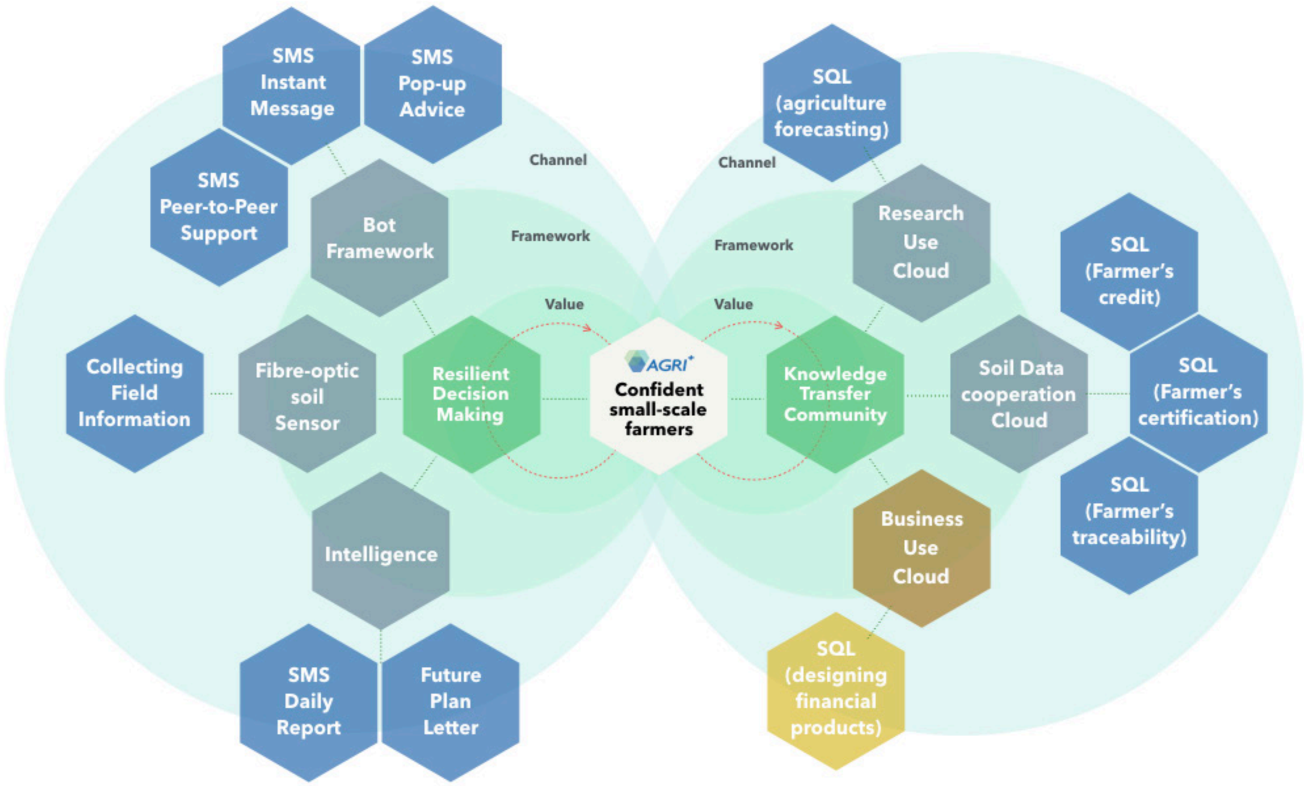
8 DECENT WORK AND ECONOMIC GROWTH

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

15 LIFE ON LAND

17 PARTNERSHIPS FOR THE GOALS



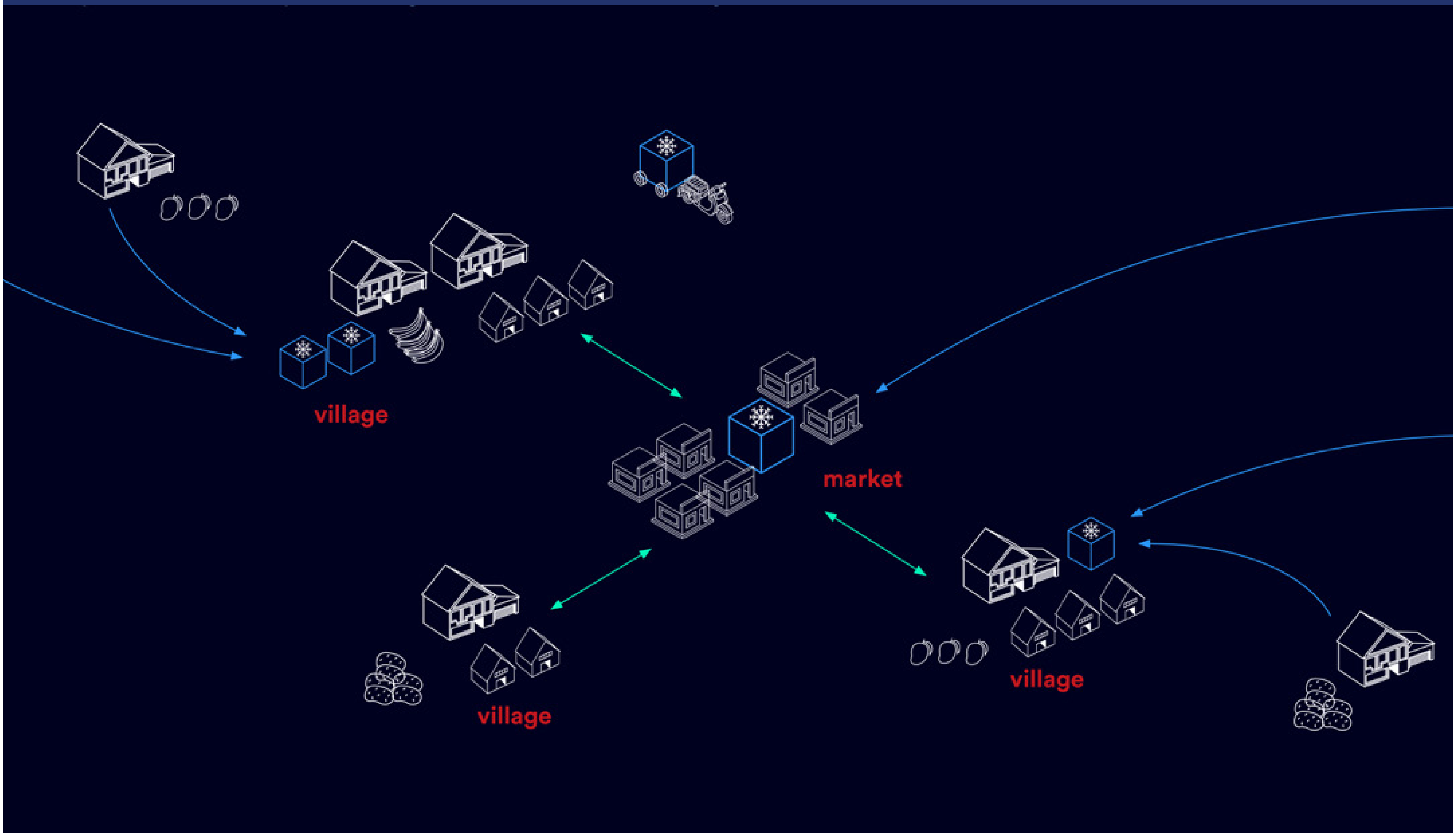
Small-hold farmers in developing economies often lack access to vital information on agricultural challenges, such as climate change or soil degradation, and economic factors like market demand, changing quality standards and price fluctuations. This puts them at an economic disadvantage and can also have detrimental effects on the environment.

Agri+ is a data intelligence platform that supports farmers in making more informed and actionable decisions, tailored to their particular crops' needs. The service uses CERN's fibre-optic soil sensors to draw data from the farmers' fields. With the help of artificial intelligence, the service combines data gathered by the sensors with large data sets from knowledge transfer networks such as markets, governments and the research sector so as to provide personalised advice to individual farmers.

The service takes advantage of the fact that 90% of small-scale farmers in developing nations now have access to mobile phones and shares bespoke insights via text message. With Agri+, farmers receive information without needing to access the internet or having to leave their farm. They can simply inquire about farming practices and receive advice from Agri+ via text message. The service aims to improve crop yields immediately, but also give advice on long-term planting plans and thereby help farmers increase their overall quality of life.

Coldbox

Anna Schlimm, Davin Browner-Conaty, Neta Steingart



Modern cooling devices run on one of the most potent greenhouse gases of all - Hydrofluorocarbons (HFCs). This gas continuously leaks into the atmosphere and, in sum, contributes greatly to global warming. The refrigerators and air conditioners in our homes are just the tip of the iceberg. A much larger percentage of HFCs are emitted by the cooling devices that power the cold chain, the temperature controlled supply chain that covers vast stretches of our planet. The cold chain is, as writer Nicola Twilley puts it, 'the unobtrusive architecture of man's unending struggle against time, distance and entropy iself'. In other words, this supply chain is indispensable and underpins much of our global economy. We rely on it to enable life as we know it; keeping products such as food, pharmaceuticals and other perishable goods fresh on their journies around the globe.

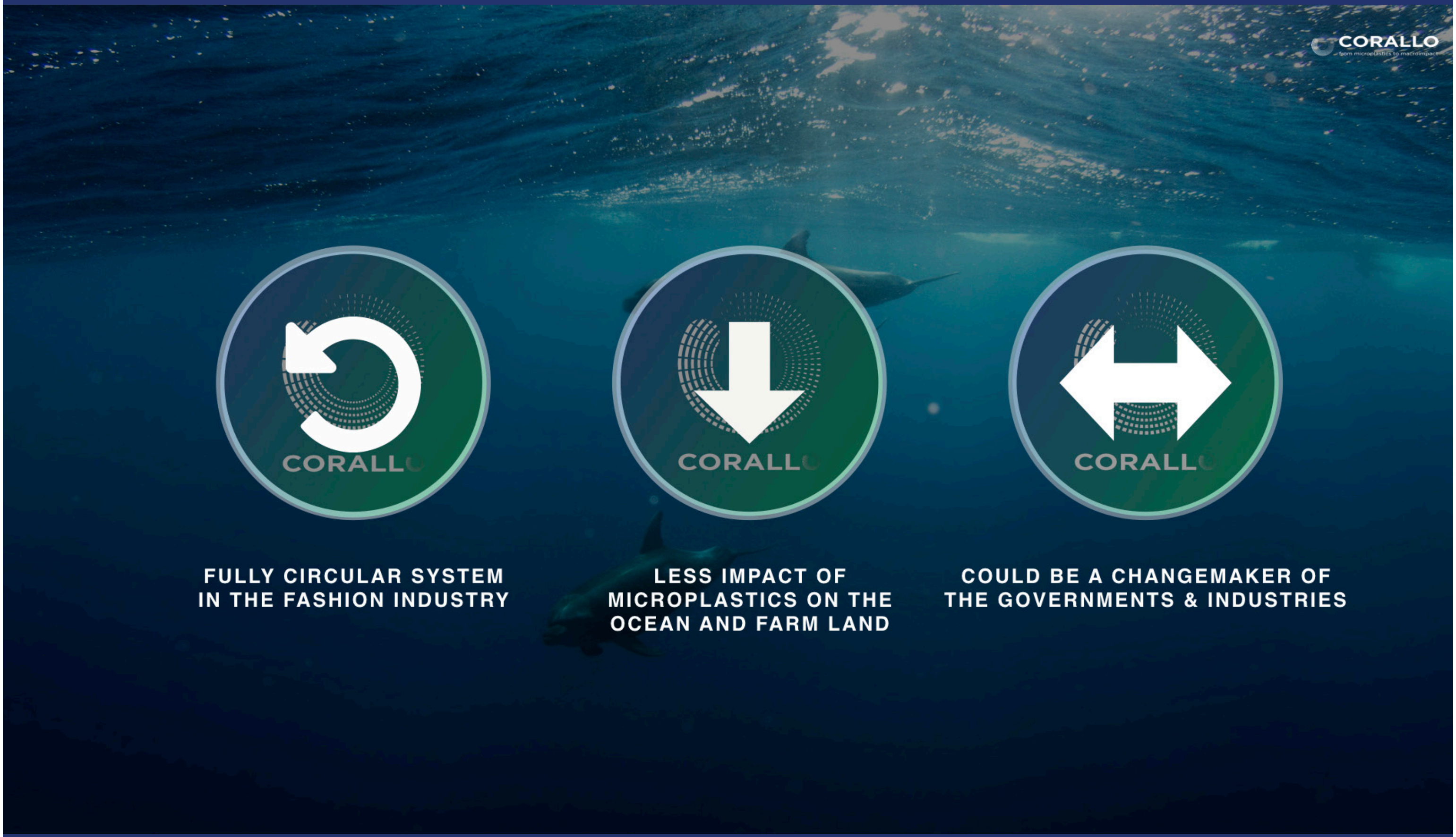
However, cold storage infrastructure does not extend to many rural and agriculturally rich areas in developing countries. This leads to staggering amounts of food loss and missed economic opportunities for small-hold farmers. Our team saw this as an opportunity to help economically developing regions to leapfrog unsustainable cooling technology and leverage CERN's solar collectors to provide a sustainable alternative. CERN's technology enables the Coldbox service to provide solar-powered, sustainable and modular cold storage units to farmers in areas where the cold chain does not yet extend.

The service, designed for maximum impact, offers two affordable ownership models. The first is shared ownership, where farmers can rent as much space as their produce needs. This model embeds the Coldbox in local markets that are accessible and frequently visited nodes of interaction for rural farmers. The second option lets small-hold farmers buy their own Coldbox. This not only enables farmers to rent out unused space, but provides a twofold opportunity: extra income for farmers and the further extension of a sustainable cold chain into rural areas.

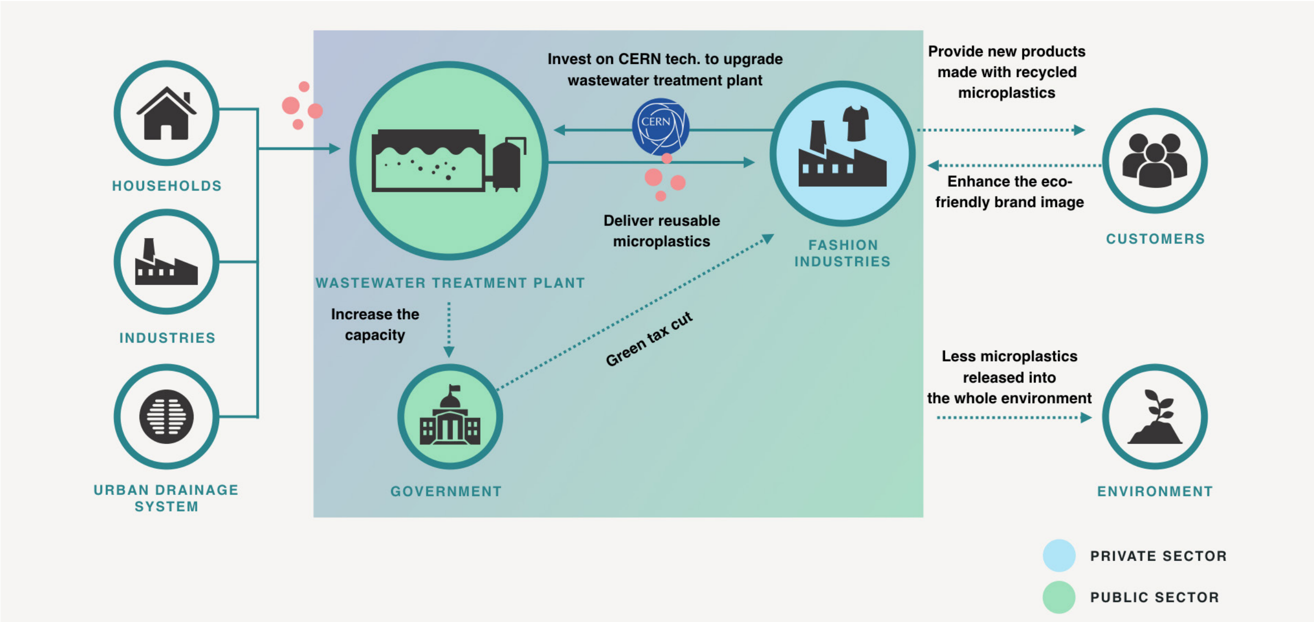
The Coldbox service was an exploration into bringing an ecocentric approach to the application of CERN's technologies. Our starting point was questioning how we could achieve a regenerative outcome for the environment. The project bears witness to the fact that an ecocentric approach does not, by definition, exclude a human-centered approach, but that the one can sit neatly within the other. In fact, it allowed us to address a more diverse range of Sustainable Development Goals, including those focused on the environment, such as climate change, and those more human-centered, such as ending poverty and hunger.

Corallo

Mattia Gobbo, Minwoo Kim, Nien-Ting Chun, Yueh Ting Chiu



14 LIFE BELOW WATER



In recent years many of the issues surrounding plastic pollution have entered public consciousness. Microplastics, however, have remained a more obscure problem. They are miniscule plastic particles that measure between 0.1 mm to 5mm and continuously enter our environment. Microplastics are the fibres that our polyester clothes shed in the wash, or the dust that car tyres give off when they wear down. Though largely invisible, these particles have become ubiquitous. They enter the food chain through fertiliser and waterways, causing harm to both human and non-human beings. For example, approximately 4 million particles are released into the world's oceans and eaten by their inhabitants on a daily basis – which means that the plastic finds its way back onto our own plates when we eat seafood, too.

Corallo is a service that creates a restorative cycle to minimise the harmful influence of microplastics on us humans and the environment. Corallo inserts CERN's technology in wastewater treatment plants, taking advantage of the fact that most microplastics pass through them before reaching waterways, and consequently food chains. Corallo aims not only to capture plastic particles, but to introduce a novel circular economy model by which these plastics can be re-used to manufacture new products, such as composite fabrics for the the fashion industry.

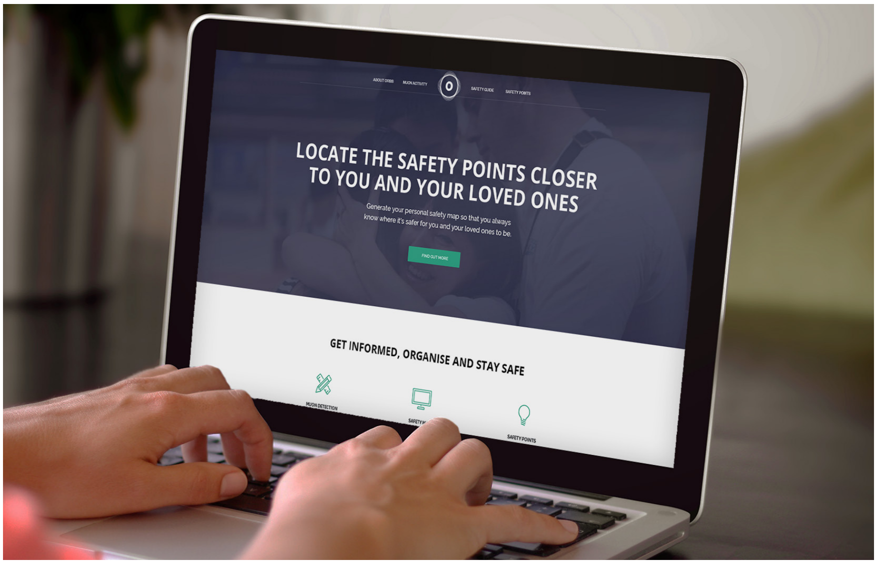
Orbis

Avra Alevropoulou, Filippo Sanzeni, Vasiliki Karaoglou

3 GOOD HEALTH AND WELL-BEING

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

11 SUSTAINABLE CITIES AND COMMUNITIES



Each year thousands of people die as a result of earthquakes, with billions of dollars spent on earthquake recovery. The scars that these natural disasters leave on both cities and their inhabitants are visceral reminders of the havoc earthquakes wreak. But they also served as our motivation - a reminder of what a difference early prediction and increased preparedness could make.

Orbis is an earthquake prediction and coordination service that makes use of CERN's open source, low cost muon detection technology. Muons are cosmic particles that pass through matter - they can reach up to 10 kilometres depth - without interacting with it. They do, however, interact with magnetic fields. The stronger the field, the more the muon's trajectory deviates from its original course. By recording and analysing this deviation it is possible to detect the intraplate stress levels of Earth's tectonic plates. From these recordings, Orbis detectors create 3D images of these stress levels and allow us to predict earthquakes up to 8 hours before they strike.

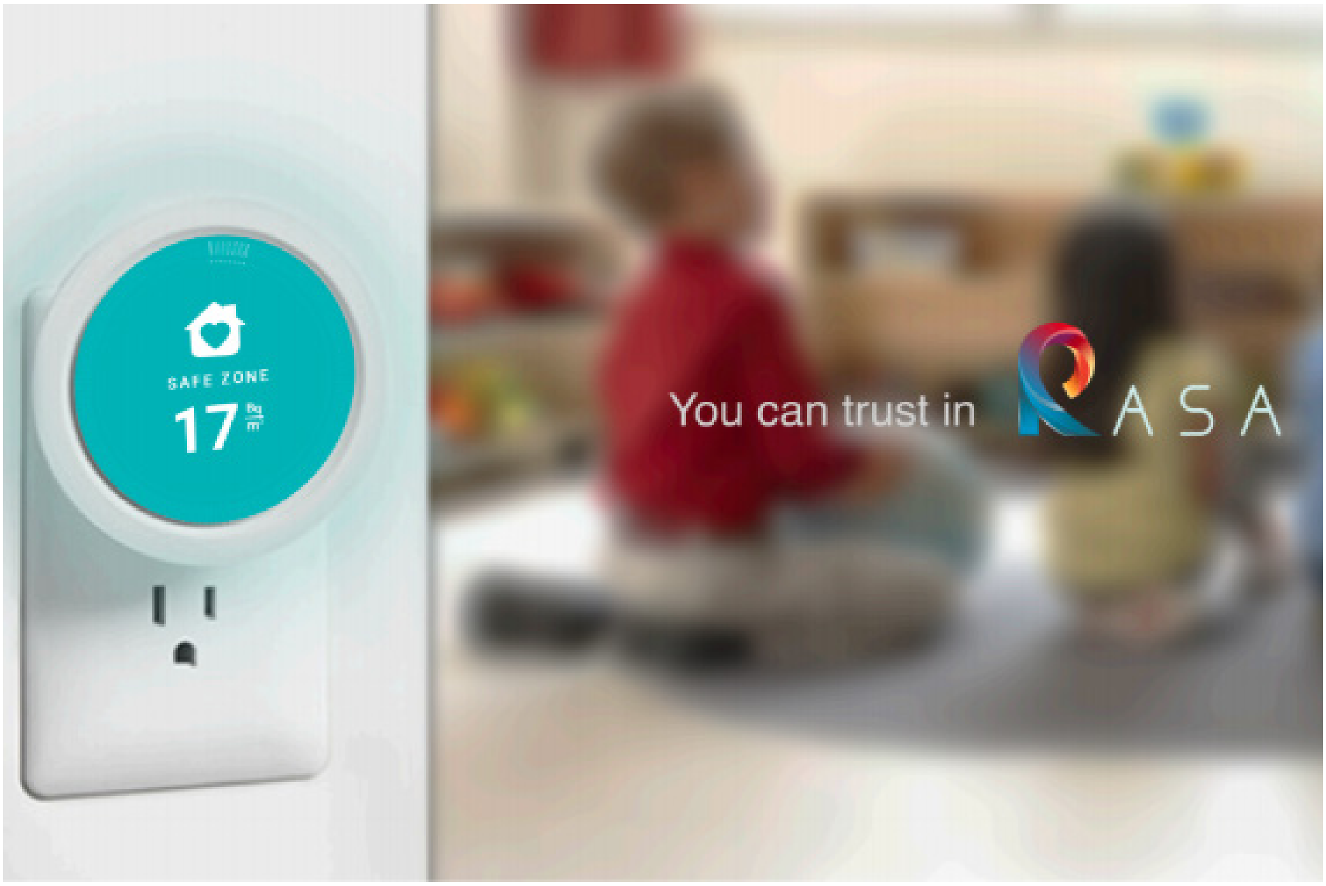
The Orbis service consists of three main components: A mesh of low-cost muon flux detectors that are installed in public buildings across seismic regions, a data collection network that processes the muon activity data and a consulting service that assists with emergency responses and crisis management planning. The low cost detectors are installed inside server racks that are located in public buildings and educational institutions such as libraries, universities, medical facilities or emergency services. This network of sensors allows Orbis to predict the exact location of imminent earthquakes. Once the prediction is confirmed the government in question can alert citizens and initiate its emergency strategy. Disaster relief teams can be mobilised in time to help citizens find shelter in temporary camps that are stocked with supplies. Orbis amplifies its impact by partnering with social media and location services, enabling the service to share vital information with users.

Orbis aims to shift response times by establishing a prediction system, increasing emergency preparedness and significantly improving the overall response coordination. With the aid and foresight provided by the Orbis system, emergency response teams can function more efficiently. This way, people could already be in shelters by the time the earthquake strikes, helping citizens stay safe. These preventative measures could also keep down expenses fo

Rasa

Boyoung Lee, Lin Chen Lin

3 GOOD HEALTH AND WELL-BEING

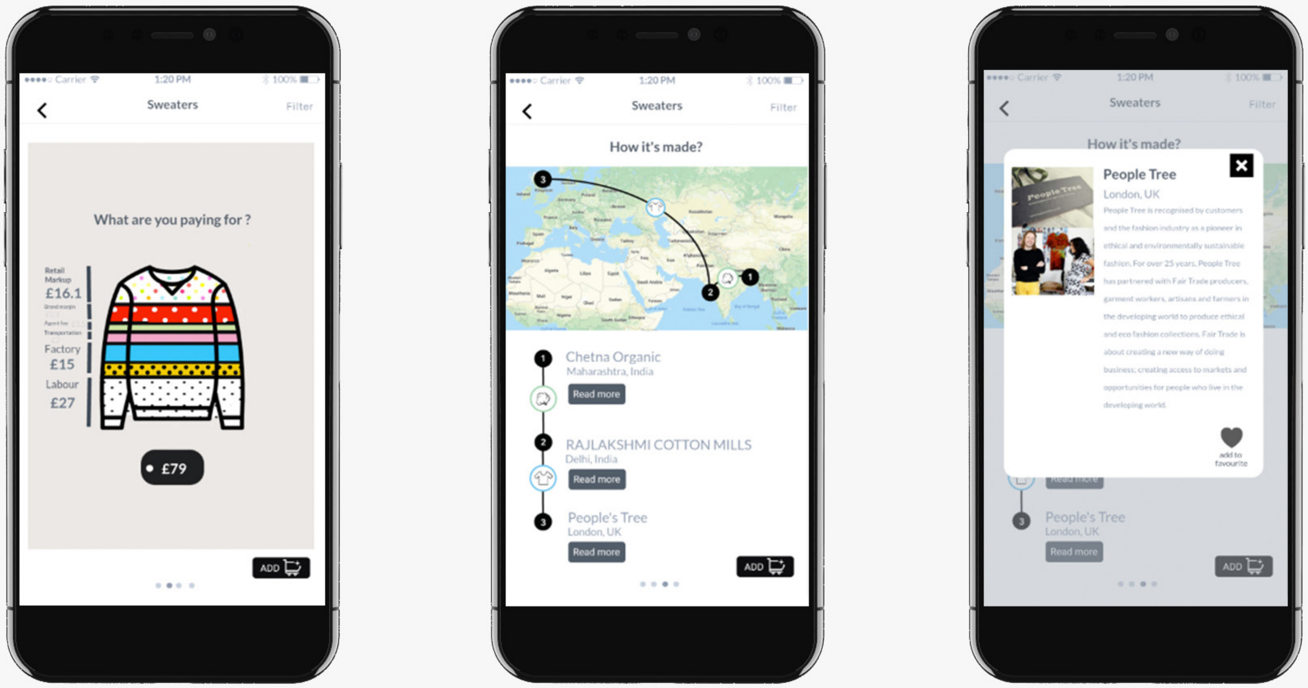


Radon is a colourless, odourless and tasteless natural gas. When radon decays, it forms radioactive elements that emit radiation. If we inhale these elements and they enter our lungs, our tissue absorbs them and they can cause localised damage. For the most part, Radon occurs in low levels outdoors, where exposure is harmless. But in areas with high radon concentration large quantities of the gas can become trapped indoors, posing a major health threat. In the UK for example, Radon is the second most common cause of lung cancer - falling second only to smoking.

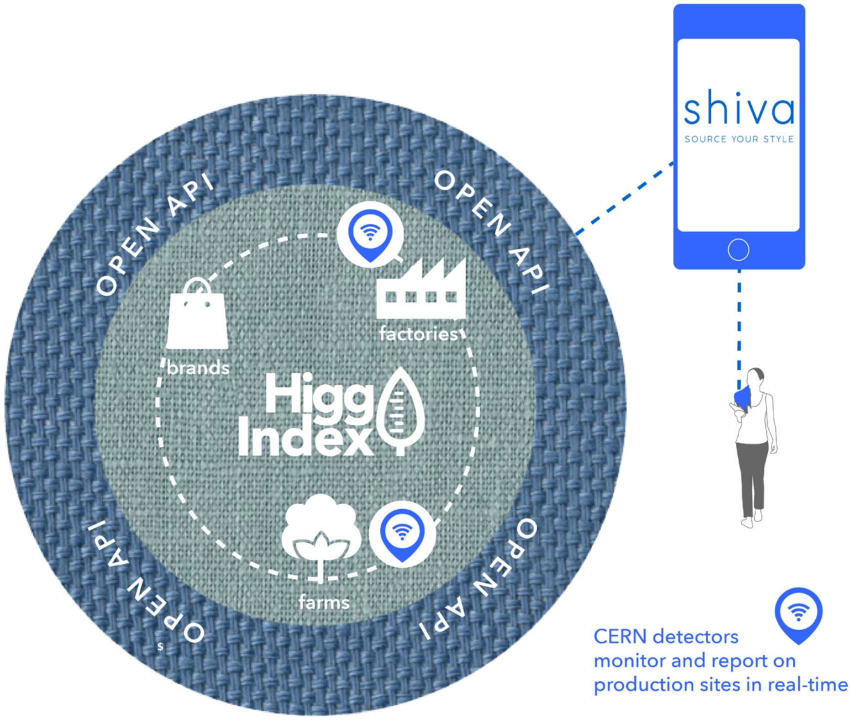
RASA uses CERN's radon detection technology RaDoM to provide an accurate, real-time radon monitoring service. The product-service system enables users to take immediate action should levels become unsafe. Furthermore, the system monitors the overall radon levels in indoor environments. It provides continuous assistance and helps clients rest assured that they are fully informed of radon levels and make sure levels are safe at all times. The service helps protect the public through preventative measures and raises awareness of the radon related health risks. RASA's primary focus is on the private sector in areas with high Radon levels in the UK.

Shiva

Rebecca Miller, Thanyawan Eamsonthi



12 RESPONSIBLE CONSUMPTION AND PRODUCTION



Shiva is a virtual fashion blogger, designed to nudge and empower consumers to adopt more ethically responsible shopping behaviours. In the near future, we imagine an array of user-centred, ethically-minded services such as Shiva that would sit on the edge of an ecosystem of innovation that is currently unfolding in the fashion and textile industry.

This ecosystem is currently emerging from within the world's second most polluting industry - fast fashion - and is led by big fashion brands themselves. They have come together to form the Sustainable Apparel Coalition and to introduce the Higg Index that helps to 'accurately measure and score a company or product's sustainability performance' by sharing best practice and data on environmental and social standards in their supply networks. By 2020 the Higg Index strives to give full transparency of fashion supply chains.

We speculate that CERN's particle detector technology could enhance the reliability and efficiency of the data collation that underpins the Higg Index by monitoring production sites such as farms and factories in real-time. Combining existing satellite capabilities for real-time monitoring of terrestrial conditions with the precise nature of CERN's particle detection technologies could offer a powerful tool for monitoring global supply chains.

This system could provide an opportunity for an open API from the Higg Index, allowing for a whole array of user-centred services; Shiva is one proposal for what a consumer facing service might look and feel like. In principle, through the power of social networks, services such as Shiva could link growing ethical consumer demand with real supply chain data to catalyse a necessary shift towards more socially and environmentally responsible practices throughout the entire fashion supply chain.

Research Findings

Once the project had been completed we explored the experience of the designers and scientists through interviews and a survey, and then later with the guests at the symposium and exhibition. We examined their overall experience in terms of the process, the project outcomes and the dissemination of the work at the symposium and exhibition, so we might better understand:

- The overall process of this project, and how the knowledge gained could contribute to improving our understanding more generally of the challenges of interdisciplinary innovation
- The process by which knowledge gained in a scientific context for one purpose might be translated into impactful solutions that go beyond the specific goals of the organization
- The technical feasibility, commercial viability, and value or desirability of the project outcomes in order to assess the relative value of this exercise beyond the educational contribution of working with CERN
- The merits of incorporating scientific knowledge, methods and an awareness of the culture of scientific discovery for designers and similarly, the awareness of design thinking within the scientific community

Feedback on the Process

We received the following feedback from the RCA designers. They commented that they were given a very open brief, but some of them suggested that a more prescriptive brief, perhaps identifying specific technologies, would have been suitable given the short timescale involved and the need to both identify which of the SDGs to focus on and which technologies to apply - it was suggested that this provided almost too many options.

There were also comments that those project teams that settled very early on a CERN technology and then built a proposition around that to address an SDG were more effective than those who started with the SDG and identified a technology that could address that need, as there were just too many options.

In order is to retain the creative opportunity they told us that the brief should not be too prescriptive, however one suggestion was for a short initial co-creation activity between scientists and designers to explore possibilities and potential directions, and shortlist both the candidate technologies and specific opportunities for a more in-depth analysis.

The designers also commented on the need to have more direct engagement with scientists making it a more collaborative effort, once a team has identified a concrete direction, and where more detailed explanations of the technologies can be made available, especially at a level comprehensible to a layperson. There were a number of comments associated with making the experience more interactive and having more direct involvement as well as pre-briefing of the scientific community. There were further comments about making the sessions with scientists more discursive rather than being in a talk or lecture format without interaction. One of the comments sums this up as “many of the presentations overlapped in content and were not necessarily tailored to an audience of non-physicist designers… it could have been a lot more inspiring and exciting for both sides if we’d had some actual intellectual exchange … (and) maybe some brainstorming sessions”

The implications of this feedback were that we should deepen the pre-briefing for both sides (RCA and CERN in this case) and structure the sessions on technology as knowledge sharing seminars and in a workshop format where applicable, as well as to acknowledge the need to adopt a language that is more inclusive, while still recognising the complexity of the science.

The value of the second visit to CERN to share the initial concepts and get technical feedback was questioned by the designers with a feeling that it could have been done by Skype or equivalent, and that it would have been more valuable to present individually to the different and relevant scientists rather than to a small group from IdeaSquare. This suggests a reflection on the project format and the pre-planning of any return visits to CERN so that the relevant scientists can schedule this in their agendas. It also suggests trying to incorporate a more collaborative approach rather than the sequential approach of a technology briefing by CERN scientists, opportunity identification and ideation by the designers and then reviewing of concepts by CERN before refining them at the RCA and presenting them back to the scientific community.

Feedback on the Solution Outcomes

The designers were in general very satisfied with the desirability of their solutions and how they addressed real and compelling needs as well as their potential impact on the SDGs. The areas they felt needed more work were around their solutions’ technical feasibility as well as commercial viability and creating a sustainable business model. Almost all of the students stated that they were eager to continue the development of their solutions should further funding be available. They also gave feedback on the technical risks on a spectrum of radical high risk to safe. They assessed their solutions as being towards the radical end of the spectrum, but with none considered to be at the extreme radical end of the scale.

The first implication of this is that greater involvement with the technology teams, not just at the start and the end of the project but also through the ideation and testing phase, would help address the technical feasibility issues, as well as encourage the students to take perhaps greater risk and use their creativity to develop more radical propositions. The second is that entrepreneurial input, especially in the latter stages to develop a business model, and a high level business plan could address the viability concern. Finally, engaging with technology investors as well as grant awarding bodies for early stage ventures could create opportunities for the potential commercialisation of the solutions.

Feedback on Dissemination

The final feedback was associated with the symposium. The comments about the symposium related to the quality of the presentations and the speakers as well as the audience. These included: "Very interesting and engaging", "More critical" and "a chance to talk with diverse disciplinary people." While the opportunities for feedback during the symposium sessions were limited, students commented very positively on the opportunity to present their work in the exhibition. "We received so much feedback from the users, experts and people... (though) it would have been good to have some more feedback from the scientists and designers in the symposium". Other comments included how the symposium could be made more effective by bringing in potential investors or people working in the industry to give feedback and create the opportunity for seed funding.

The symposium and related exhibition format were very well received by the audience which was drawn from industry, academia and the public sector. Comments included how "imaginative", "inspiring", "the solutions are so complete in their thinking, so well researched, and the technical depth so unexpected" as well as comments about the overall importance of interdisciplinary innovation models where designers play a lead role.

The comments from the designers highlight the value of having a format that enabled them to exhibit their work as well as present it in the more formal context of the symposium sessions. The audience that the seminar attracted was very diverse, but consistently at a high level with representatives from senior roles in other universities, museums and public institutions. Future dissemination events would provide the opportunity to include potential project funders from industry, the VC and Angel communities as well as award bodies. It could also be valuable to present this work within CERN in a similar format, and use this as a means to inspire scientists to consider how their innovations might be applied to opportunities beyond CERN in order to make a contribution to the grand challenges we collectively face.

Conclusions

We have summarised the new knowledge from the project with six key recommendations that can guide not just future projects that involve interdisciplinary innovation involving scientists and designers, but may also be more generally applicable.

They are as follows:

1. *Managed Serendipity:* There is an appetite within the scientific community to see their scientific discoveries and technology innovations being applied to opportunities beyond CERN. However, the project identified that the current model relies more on serendipity than an analysis of strategic opportunities and issues such as the UN SDGs at one extreme or Elon Musk's Hyperloop and its need for hyper-vacuum technologies on the other.
2. *Focusing and intensifying the "Radar":* There is therefore an opportunity for Knowledge Transfer teams to undertake a systematic review of what might be referred to as "Grand Challenges", potential industry and governmental partners and to effectively scout for science and technologies that could contribute to resolving these challenges within organisations like CERN.
3. *Start with the problem:* A design led approach that starts by deconstructing the challenge, and building an understanding of the needs and constraints of the key stakeholders associated with that challenge, can be a more fruitful way of defining the opportunities that a scientific discovery or technological innovation might resolve. Starting with a technology and looking for a problem to fix tends to result in applying a distorting lens on the problem, so it is then is shaped by the possible solution. This has implications to knowledge transfer programmes in general within scientific organisations.
4. *Mutual Understanding:* The importance of pre-briefing and orientation – it was evident from the experience, both of the students as well as from the scientific researchers, that undertaking better pre-briefing of each party would enable a deeper understanding of each others capacity and approaches.
5. *Spaces, Places and Visualisation of Ideas:* The IdeasSquare space created an environment that was distinctly different from the rest of CERN and more conducive to the exploration of ideas and the generation of concepts in an uncritical manner. Those ideas, once reflected upon and synthesized, could be scrutinised rigorously, but without these conditions it is hard to enable creative concepts and ideas to emerge. Importantly, the RCA students' capacity to develop those ideas through visualisation, story telling and prototyping so that the systems concepts could be understood in their entirety was crucial in generating confidence within the scientific community of the robustness of the ideas.
6. *Translating Ideas to Impact:* The process of dissemination is not yet fully complete, but the symposium enabled the

ideas, concept solutions and innovation approach to be shared with interested parties beyond CERN and within academia and industry. However, the opportunity remains to publish and exhibit the outputs of this work as well as build upon it, and use publications such as this one to share alternative approaches to identifying opportunities for the technologies that emerge from CERN and link them to global social, environmental and economic challenges. As a next step it is important to share these outcomes with industry and governmental partners not only as sources of inspiration but as concepts that could be taken further. In this case, consideration might be given to creating a venture incubator and business accelerator as part of the KT function, where emergent concepts can be supported to a point where the private sector might be ready to invest, or partner in their development.

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