# Future and Emerging Art and Technologies


**Art & science collaborations: boredomresearch & subCULTron; Evelina Domnitch and Dmitry Gelfand & RySQ; Anna Dumitriu & MRG Grammar; Miha Turšič and Špela Petrič & INTERTwinE; Semiconductor & QuProCS; Pinar Yoldas & DIACAT; Kerstin Ergenzinger & nuClock**

# Contents

# Preface

*FEAT*
This catalogue documents the processes and outcomes of unique and in depth collaborations between artists and scientists exploring the fields of synthetic materials, nuclear time measurement, quantum physics and quantum computing, gene regulation, high performance computing and underwater swarm robotic cultures.

These cutting edge collaborations are the result of the FEAT: Future Emerging Art and Technology project. FEAT is supported by the EU programme FET Open. FET stands for Future Emerging Technologies. FEAT is a support initiative to inform and advise the European Commission about best practice methodologies for the arts to engage meaningfully with techno-scientific research and developments in emerging technologies, considering complimentary methods, critical reflection, widening public engagement and potentially enhancing take up in potential future technologies.

The FEAT project invited new and recently started FET supported research projects, to be paired with artists that were selected by a jury via an open call for participation. After a two-day gathering of researchers and artists meeting each other and learning about each others' work the artists chose to work with the projects that most inspired them. Six pairs were selected to participate in a fully funded nine-month period of collaboration working with together embedded in laboratory settings, studios and workshops. All the invited FET projects accepted the FEAT invitation and no less than 267 high profile artists applied to the successful open call.

*The six pairs*
- Vicky Isley and Paul Smith of boredomresearch with subCULTron led by Roland Thenius of the University of Graz.

- Evelina Domnitch and Dmitry Gelfand with RySQ, led by Robert Spreeuw of the University of Amsterdam.

- Anna Dumitriu with MRG-Grammar led by Dr Roee Amit, Technion, with collaboration from Dr Sarah Goldberg, Dr Adina Weinburger, the Weizmann Institute, and Professor Sarah Teichman, The Wellcome Sanger Institute.

- Spela Petric and Miha Tursic with Exascale projects (INTERTWINE and Mango) led by Dr. George Beckett of the University of Edinburgh and with collaboration of Mario Kovac of the University of Zagreb.

- Ruth Jarman and Joe Gerhardt of Semiconductor with QuProCS led by Sabrina Maniscalco of the University of Turku.

- Pinar Yoldas with DIACAT led by Anke Krueger of the University of Würzburg.

*Seventh pair*
Apart from the six selected pairings, one additional pairing is included in this catalogue, that of Kerstin Ergenzinger with Simon Stellmer of the NUClock consortium. Stellmer and his NUClock team were disappointed that they were not among the chosen ones after the initial two-day session at the Theatrum Anatomicum of the Waag in Amsterdam where artists and researchers first met and chose each other. Consequently, they decided to invite and financially support an artist within the FEAT project. They chose Kerstin Ergenzinger to be resident artist within the research team for the four-year term of the NUClock project.

The results of FEAT are diverse in terms of how they allude to the original research question of the roles that art can take on in collaboration with techno-sciences, ranging from communicating new scientific research from an aesthetic perspective to coming up with new research questions and critiquing emerging techno-scientific development and ethical issues.

Art and techno-sciences collaborations are not new, but the way they happen within the FEAT project is unique. Artists get full access to research and to the labs of large emerging technology research consortia with distributed facilities across the EU and beyond. It is important that the artists get the chance to

embark as early on as possible upon fundamental and high-risk technology research. It is also new that there is broad interest from research teams at large, not just that they are curious about artists disseminating their findings better, but also that they are interested in artists questioning their processes and findings not least because that may lead to new research, new collaborations, new findings, and potential innovation. It is also important to bring the processes and results of the interactions to new realms, inviting the techno-scientific researchers to become part of arts programmes and events and bring the arts to scientific conferences offering them a stage where they can show that they can offer more than traditional science communicators, reaching out to not only professional audiences but also a broad general audience and creating exchange not only between art and science, but also between policy makers and society at large.

Art also has the ability to communicate complex research in different ways. Being material, tactile, visual, audible, participatory, art offers alternative ways to communicate ideas in science contextualising and re-contextualising it within society and culture. In this way it offers science itself a mirror and a space for reflection to break out of its normal confines and receive novel perspectives. This leads to another essential perceptive that art can bring to the techno-sciences: ethics. Like art, science is also influenced by aesthetics. Aesthetics are an important carrier of meaning including emotional meaning, through which we can understand personal and collective concerns and fears around the impact of technology on our lives. Artists can work with these aesthetical and ethical considerations and help us refine new research questions to develop technologies for positive social change.

The influence and effects, the tools and means of technology and techno-sciences are increasingly becoming part of our daily lives. Its further development is of interest to all of us, not just its current 'makers': scientists and engineers. In this context, FEAT can also be seen as an attempt to broaden and enrich the field of scientific research by involving artists as they pursue research with the same curiosity-driven motivation, but they ask valid and valuable questions from the opposite end of the spectrum, from a personal and very subjective position, from an humane and responsible perspective.

In this catalogue, you will find evidence of the exchange between artists, scientists and engineers and about the way in which they mutually value their research and possibly influence each other's research questions. Given the effort that our European society puts into knowledge production and understanding what the real challenges are it faces and it will face in the future, there can be benefit from the enrichment of artists in the realms of emerging technologies research and beyond. Let this exchange be a continuation of arts and artists' interest in science and emerging technologies, and let it be the beginning of engaging them more fundamentally in the European Commission's Framework Programmes to come. Enjoy reading and being witness of meaningful exchanges and productive misunderstandings between the arts and emerging technologies.

In this catalogue, you find visual documentation of the artworks, the art-science interactions and their processes of making. The visual documentation includes the exhibition texts written by curator Sarah Cook of the LifeSpace Gallery at the Life Sciences faculty of the University of Dundee in Scotland. You will also find essays by the artists and scientists involved in which they give both general and sometimes very detailed views on the collaborations. You also find some clarifying texts about the involved fields of researched technologies. Also included are the articles originally written for and published in MIT Press Leonardo Journal.

# FEAT Events

Apart from numerous presentations about the project in general and of the collaborations by the project partners, the artists and the involved researchers, FEAT presented itself and developed is activities and workings during the following events:

Opening workshop and matchmaking at the Anatomical Theatre of Waag Society – 17, 18 March 2016, Amsterdam, Netherlands

Knowledge in Art Science and Technology Workshop 27, 28 June 2016 at Austrian Computer Society, Vienna, Austria

Presentation of the collaborations and panel discussion “Are we doing this right?”, 8 September 2016 during Ars Electronica, Linz Austria

Exhibition of the FEAT Art Works at Life Space gallery at the Life Sciences faculty of Dundee University, Dundee, Scotland, 13 April, 17 June, 2017

Panel discussion about the FEAT collaborations and their future, 8 September 2017 during Ars Electronica, Linz, Austria.

Presentations of FEAT model and artworks during the Estonian EU Presidency STARTS Symposium, 14 September 2017, BOZAR – Centre for Fine Arts, Brussels, Belgium.

# Introduction of the exhibition at LifeSpace Dundee (UK)

Scientific research is a collaborative affair. Teams from across academia and industry work in partnership to solve problems and test new methods. What goes on in this building is a testament to the interdisciplinarity required for ground-breaking research. We are now half way through the European Union's major research programme – Horizon 2020 – which is allocating €80-bn to research that aims to strengthen the EU's position in science, foster industrial innovation (ensuring technological breakthroughs are developed into viable products with real commercial potential) as well as research that addresses major social concerns (such as climate change and renewable energy). The six works of art in this exhibition are directly the result of EU-funded research into new and emerging technologies, which seek to solve diverse problems from carbon capture to monitoring pollution.

What role can artists play in collaborative scientific research? This exhibition suggests some answers (and one of them isn't better-designed scientific posters). The FEAT project – Future Emerging Art and Technology – has paired artists with FET research consortia across Europe. The goal: to explore unconventional ways of thinking and technology. The result: works of art that may be in keeping with the artists' own ways of working, but on radically different topics than we usually think are the concern of artists, from quantum physics to supercomputing.

The works in the exhibition ask us to understand the content of complex research projects from a totally different perspective: that of the artist. They also suggest the potential of involving artists in scientific research projects to create engaging, persuasive and experimental reflections on the bigger picture – the real-world implications of that research, at a human scale.

The artists whose work is included here are some of the most exciting working today. Through their explorations – most shown here for the first time – it is hoped that a greater awareness of new technologies ensues, and new societal discussions are opened up.

FEAT is funded by the EU backed programme FET (Future and Emerging Technologies) Open. It has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 686527 (H2020-FETOPEN-2015-CSA).

This exhibition is organised by FEAT (Future Emerging Art and Technology) an initiative of eutema GmbH (AT), Stichting Waag Society (NL), and youris.com (BE) in collaboration with LifeSpace.

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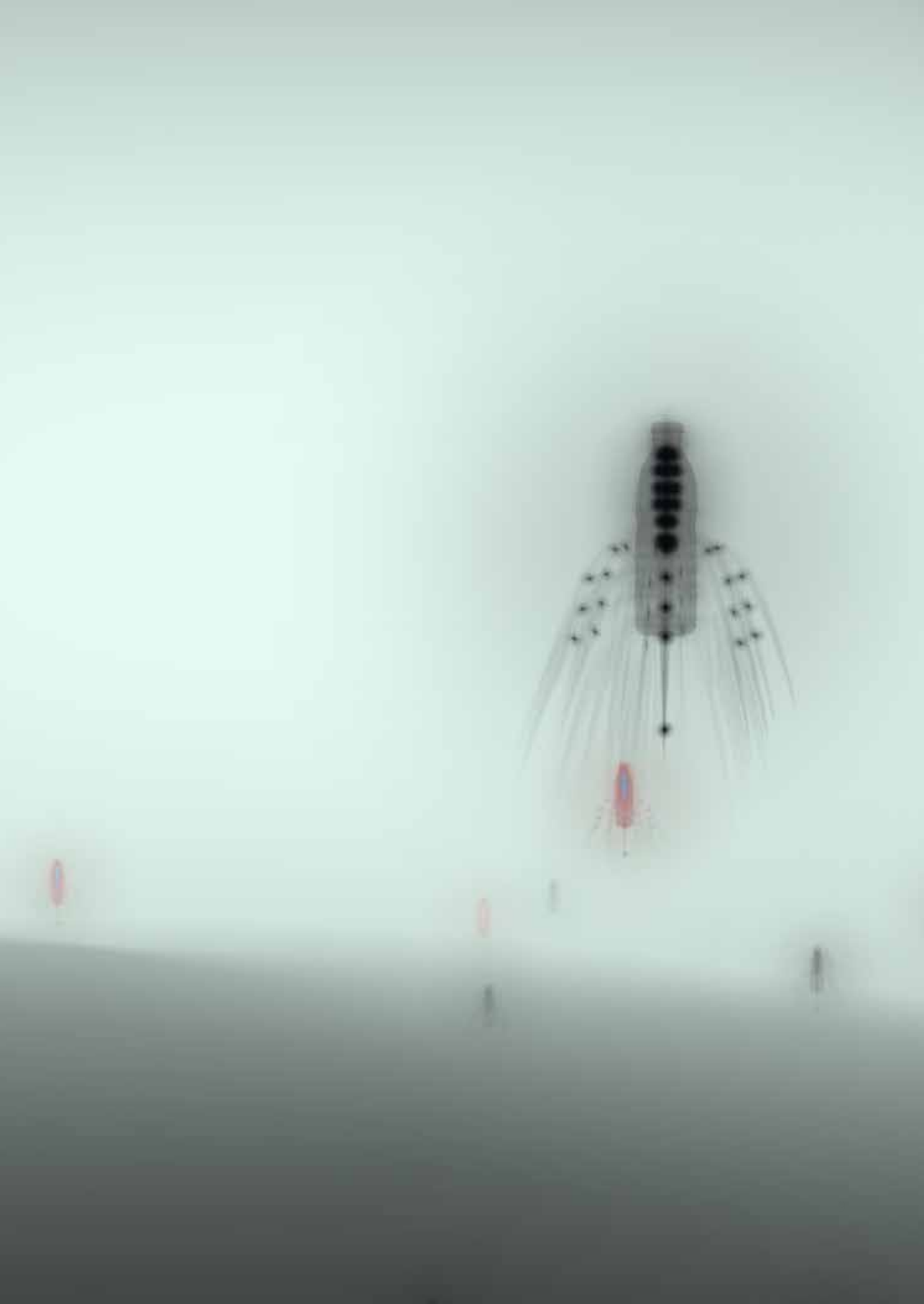
# boredomresearch & subCULTron

FEAT



# boredomresearch

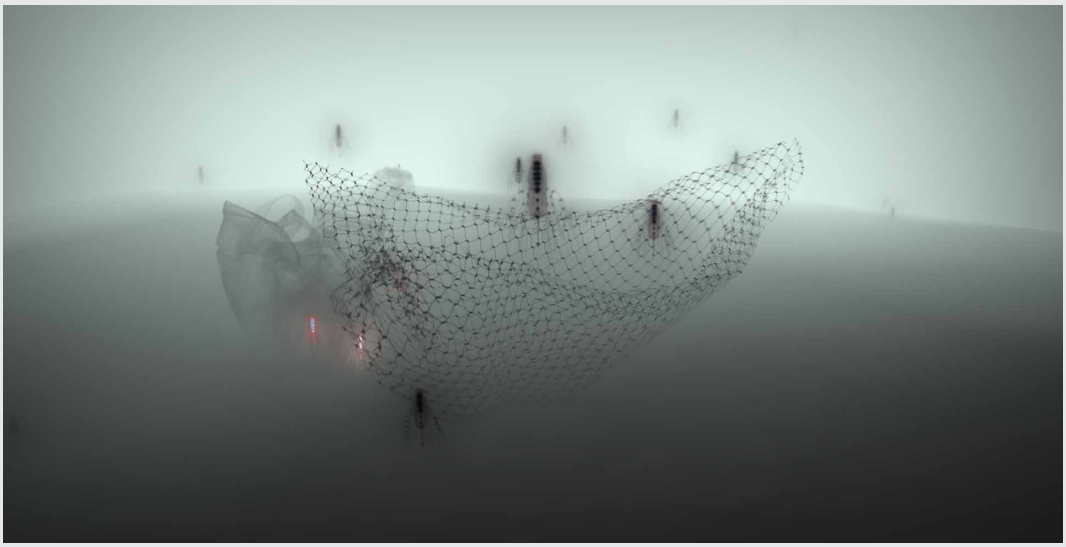
boredomresearch is a collaboration between British artists Vicky Isley and Paul Smith, their work benefits from a long lasting fascination in the mechanics of the biological world which they explore using contemporary technology. Their work transcends boundaries between art, science and society, with previous projects exploring topics including: the intricate biological signatures of neural activity, the frontiers of disease modeling and our cultural obsession with speed.

With two decades of artistic practice, exploring an understanding of the natural world through the medium of computational technologies, boredomresearch have become intimately aware of the sensitivity and vulnerability of complex systems, including those which support human life on earth. boredomresearch have been working in collaboration with world leading science institutions across Europe creating artworks developed from ground breaking research. Their collaboration with Dr Paddy Brock, a mathematical modeler at the Institute of Biodiversity Animal Health and Comparative Medicine at the University of Glasgow, led towards the creation of AfterGlow. This new representation of malaria infection transmission addressed the limitations of existing models and was awarded, in September 2016, the Lumen Prize moving image award.

Their seminal work Real Snail Mail (the world's first webmail service to use real snails) challenged our cultural obsession with speed, highlighting perverse socio-economic distortions, centered on ideas of productivity, which exploit technological innovation to enslave humankind in a work life imbalance that continues to deteriorate despite the introduction of numerous 'time saving' technologies. Receiving worldwide attention, including: BBC, TIME Magazine, New Scientist and Discovery Channel Canada, this and other works by boredomresearch, open channels for meaningful dialogue and engagement between public and scientific domains.

The artworks of boredomresearch are in collections around the world including the British Council and Borusan Contemporary Art Collection, Istanbul. Recent international exhibitions include: Balance Unbalance 2016, Manizales; Bio-Art 2015, Seoul; ISEA 2015, Vancouver; TRANSITIO MX_06 Electronic Arts & Video Festival, Mexico City in 2015; Soft Control: Art, Science and the Technological Unconscious, Slovenia in 2012 and Gateways, House of Electronic Arts, Basel in 2012.

www.boredomresearch.net



## subCULTron

Project subCULTron aims to develop an autonomous underwater robotic society comprising of three swarms of bio-inspired robots that monitor the environment in a marine habitat.

The three robotic swarms forming the society are:

1) “aPads” which are robots that act as base stations on the water surface for docking with other swarm members, communicating with external entities, collecting solar energy, etc.

2) “aFish” which are a group of agile robots which can move around underwater for exploring new areas and exchanging information between sub swarms.

3) ”aMussels” which are a swarm of robots with very low power consumption. They dive down to the water body bed to collect data and energy.

This robotic society will be deployed in the environmentally diverse and dynamic lagoon of Venice. The subCULTron system stands out from traditional engineered systems as it utilizes a combination of the strengths of classical control systems and naturally occurring swarm intelligent behaviours to accomplish its goals.

The focus of the subCULTron project is on utilization of bio-inspired behaviours, cultural learning, swarm behaviours for increased stability and adaptability in harsh environments. Apart from contributing to the scientific community by developing novel bio-inspired behaviours and implementing a real world application of a robotic swarm, the subCULTron system will also gather enormous amounts of environmental data which can be used to fine tune nature preservation policies, industrial techniques etc.

The subCULTron project is conducted in consortium with eight partners spread across five countries in the European Union. The project is being coordinated by the Artificial Life Lab at the Institute of Zoology, Karl Frazens Universität, Graz, Austria. The Artificial Life Lab, under the leadership of Prof. Dr. Thomas Schmickl, specialises in research on swarm intelligence. The lab focuses on experiments with swarm intelligent animals and also on the implementation of findings on simulated and real robotic swarms. If you are interested to get updates about subCULTron project, please follow the twitter handle, “subCULTron”. For more details about the Artificial Life Lab, please visit the website: zool33.uni-graz.at/artlife

# Robots in Distress

Robots in Distress ponders the nexus of biology, robotics and environments impacted by increased human activity; confronting the emergence of synthetic emotions in challenging environmental circumstances. boredomresearch present a murky underwater world populated by glowing craft. Navigating the hazards of a terrain heavily polluted with plastic waste these craft are learning to recognise and express hopelessness. This expression of emotional robotics inquires on the relationship between organism and its environment and responding to an increased dependence on advanced technological solutions.

The work follows a residency at the Artificial Life Lab (Karl Frazens Universität, Graz Austria) where boredomresearch gained an insight into the process by which highly engineered and technologically advanced, robotic interventions are conceived, designed and fabricated. The lab is developing a community of bio-inspired robots, operating, in the heavily human polluted environment of the Venice lagoon. These highly engineered robots, often start life as experiments built from freely available materials, including the very same plastic waste that pollutes marine environments. Mirroring this process boredomresearch worked with a subCULTron engineer to explore the motion dynamics of micro-controlled plastic waste, which later informed the craft seen exploring the mysterious underwater world of the artwork.

The agents design is also informed by the labs use of simple bio-inspired control mechanisms, inverting a cultural tendency towards increased complexity, with eloquent and simple algorithms that create rich and complex behaviour. An example of such behaviour is an algorithm known as BEECLUST where, on meeting, robot agents pause for a duration, increasing in desirable environmental circumstances. This leads to a swarm intelligence able to locate favourable environmental situations. The potential for artificial emotions to provide increased diversity of behaviour was another concept presented to boredomresearch. They were shown a computer simulation of Braitenberg vehicles with two wheels and two sensors connected by artificial synapses. In this case the inclusion of a simulated hormone gland, providing a feedback mechanism, was exploited to increase the efficiency by which they could locate and consume resources. The artwork produced by boredomresearch attempts to use a similar mechanism to promote despondency, allowing the craft to recognise the existence of a hopeless situation. Ultimately, they present a new vision for technological innovation. One recognising the fragility of the environment, through which we can consider our strategies for coping in a world increasingly destabilized by human activity.

# Robots in distress in the Venetian Lagoon

*Two British artists are designing an unconventional fleet of autonomous devices that can help fight pollution in the lagoon environment of Venice.*

*13 October 2016*

Can mathematics be expressed poetically through computational technologies? Visual artists Vicky Isley and Paul Smith believe it can be and are collaborating with the Artificial Life Lab of the University of Graz, in Austria, on the Subcultron project (Submarine Cultures Perform Long-Term Exploration of Unconventional Environmental Niches). They want to create swarms of little robots to check the environmental status of the Venetian Lagoon.

The two British performers, who formed an artistic - and life - partnership 20 years ago known as boredomresearch, will unveil their results in 2017, but they gave youris.com a preview. “We can’t say much about the outcome yet as we are still in an exploratory phase,” says Smith. “For sure our work will revolve around the motion of plastic waste for which we’re working on microcontroller robots, which should be robust enough to operate in a harsh and polluted environment such as the lagoon.”

What makes this project special is that it’s aiming at creating the world’s largest intelligent underwater monitoring system that coordinates, communicates and collects data autonomously. It will do this via a society of self-organising underwater robots. These come in different typologies, from artificial mussels that sit in a fixed place underwater collecting data, to floating artificial lily pads that form the point of contact (or communication) with the humans on the surface of the water. And in between, the artificial fish moving and monitoring larger portions of the aquatic environment.

“The autonomy of robots and their capacity to make decisions are fascinating aspects of the project,” says Isley. “Their behaviour is in part determined by learning algorithms. But because of their learning capacity, the evolution of their specific culture is not predictable. We thought this would be a great inspiration for our work.”

And yet the artists’ perspective in this type of challenging research is not an easy one. “After our first visit to the lab in Graz, we’ve realised that we need to face some practical issues,” Isley continues. “When we started to talk to the researchers about the longevity of the robots used in the project, they said they are long term autonomous robots living for about a week. This is a challenge for us, as a week is not a very long time for an exhibition. Now we are looking into wireless charging under the surface of the water.”

“Also, the design and robustness of our own robots are crucial,” adds Isley. “We are trying to build robots out of plastic waste, the key concept is to reflect the motion of plastic waste in water, but some of our microcontrolled motors got strangled and stopped working. So this led us to also contemplate the idea of introducing death as one of the variables in our work. In the end our robots might live and die in this sort of plastic soup.”

This is not the first time that boredomresearch has confronted complex dynamics. One of their recent works, AfterGlow, looked at the relationship between the transmission of human infections and the landscape, immersing the viewer in a blizzard of infectious dynamics.

*By Rebecca Parsons*

# The art of non-deterministic behaviour

*From the dreams of a mouse to real snail email, "boredomresearch" extract the poetic dynamics of natural complex systems.*

*14 December 2016*

You do not necessarily need to look crazy to do crazy stuff. If you met Paul Smith and Vicky Isley in the corridors of Bournemouth University, where they teach Computer Animation, you would hardly imagine what these researchers and artists are busy with.

And you would probably be surprised to learn that one of their recent works has to do with the visual expression of the dream of a mouse, where impulses recorded through a subdermal implant are translated into a visual and acoustic dynamic enlightened by firing neurons.

The outcome of the project, completed in 2015, in collaboration with Dr. Vlad Vyazovskiy, a neuroscientist at the University of Oxford, is a rather intimate storm of neural activity recorded with a real time engine during a mouse's sleep.

Under the name of boredomresearch, Paul and Vicky form a consolidated artistic partnership that enjoys a frequent crossing of borders between science, technology and society. "We're fascinated by the form that natural phenomena can take when translated into computer based vision", says Vicky Isley.

With a more recent work, called AfterGlow, boredomresearch won the Lumen Prize in the Moving Image category. The concept was to explore the spatial qualities of disease transmission, working on data and dynamics related to the spreading of a malaria infection in a population of macaques, a project developed in cooperation with Dr Paddy Brock, a mathematical modeller at the University of Glasgow.

As a result, the viewer is taken into a landscape where the infection scenario unfolds in glowing trails, inspired by mosquito flight paths, and is then animated by the infected macaques wandering in search of food.

"We wanted to express a strong relation between the disease and the environment. Works like Afterglow challenge us in the sense of developing mathematical models to explore complex systems as they exist in nature. Our perspective is to create agents or use artificial life to develop scenarios where non-deterministic behaviour occurs, which may actually add to the complexity of the dynamics we want to observe and express", says Paul Smith

Another undertaking by boredomresearch has to do with our society's obsession with speed. The answer of the British artists to that is the Real Snail Mail project, where real snails contribute their slow-ware share to delivering emails.

Since May 2016, boredomresearch are running a residency at the Subcultron project, a collaborative research led by the Karl-Franzens University of Graz, Austria, to deploy a broad society of autonomous little robots in the Venice lagoon.

# Simulated Despondency for Robots in Distress

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*Submitted: 7 March 2017*

**Abstract**

It is widely accepted that increased human interaction with natural systems is responsible for complex environmental issues, with most current thinking, centered on the provision of advanced technological solutions. One response emerging from current bio-inspired robotics research, proposes artificial neural networks (ANN) enhanced with the incorporation of artificial hormones for increased performance and efficiency. Here the authors discuss their artistic project concept, developed in collaboration with a bio-inspired artificial life lab, considering the affordance of emotional robotics to develop despondency in the field.

*Keywords:* Robotics, emotion, artificial neural networks, simulation, distress

## An Artistic Response to Bio-inspired Robotics

For the last two decades our artistic practice has explored an understanding of the natural world through the medium of computational technologies. When we attended the Future Emerging Art and Technology (FEAT) matchmaking event [1] we were intuitively drawn to the research behind the subCULTron project (Submarine Cultures Perform Long-Term Exploration of Unconventional Environment Niches) which is heavily influenced by biological processes and mechanisms. subCULTron is a Future and Emerging Technologies (FET) project [2], consisting of a consortium of scientific research labs in Europe working across advanced robotics and bio-inspired simulation, with the aim to achieve long-term autonomy in a learning, self-sustaining underwater culture of robots in a high-impact environment. During our FEAT residency in 2016 we immersed ourselves in subCULTron's, Artificial Life Laboratory of the Karl Franzens University Graz in Austria. This took us into a new area of consideration as we explored the transition from simulated software worlds to robotic interventions in natural environments. At the start of the residency, we were presented with a simulation of the Braitenberg vehicle model, consisting of two wheels, two sensors and two artificial synapses. The simulation presented a modification with an addition of artificial hormones. This model of emotional robotics evidenced increased efficiency when faced with the task of seeking and consuming resources, "After 10,000 time-steps the agents with a hormonal system had evolved a controller that is significantly more efficient than agents without a hormonal system" [3]. Efficiencies like those evidenced in this paper can have significant value in the field. For us this did however raise some interesting questions especially when viewing the frenetic behavior of agents hungrily consuming resources with a seemingly insatiable appetite. This led us to consider whether there might be an alternative vision for emotional robotics.

## Environmental Crisis and Melancholy

Following Marvin Minsky's argument that: "The question is not whether intelligent machines can have any emotions, but whether machines can be intelligent without any emotions" [4] it is worthy to consider the significance of negative emotions in the human condition. Current frames of reference, like those informing Becks Hopelessness Scale [5] evaluate emotional responses to failure, including despondency, as harmful. "They interfere with normal cognitive processing, leading to impairments in perception, memory and problem solving" [6]. Clinical practice offers, by way of remedy, a range of therapeutic solutions from psychoactive drugs to psychotherapy.

In contrast, much commentary of twentieth century art, celebrates artifacts produced subject to a heightened negative emotional state. For example, Vincent van Gogh's archetypal anguish, "one feels as if one were lying bound hand and foot at the bottom of a deep dark well, utterly helpless," [7] offers a contradiction between the adverse effects of melancholy and valued artistic expression. Though we share objections, to a myth of tortured genius, we do acknowledge a connection between concepts of value and negative emotion. We also argue that this specific type of value goes beyond that which satisfies standard economic interest and may, in contrast to a one dimensional pursuit of happiness, form an important function in addressing complex environmental relationships. As Ziemke and Lowe state, "Emotions track bodily states that reliably co-occur with important organism—environment relations, so emotions reliably co-occur with important organism—environment relations" [8]. In Against Happiness: In Praise of Melancholy, Eric G.Wilson adds *'positive psychology'* to a list of concerns including nuclear proliferation, global warming and environmental crisis, arguing that a current happy centric bias tricks us to behave "as predictably and artificially as robots," warning of "wastelands of mechanistic behaviour" [9].

We argue that the role of negative emotions in humans remains unclear and therefore should not be excluded from consideration in advanced robotics. It is clear that negative emotion is central to the human condition, and may be important in our evaluation of complex long term environmental challenges. Furthering the use of simulated hormones in ANNs to increase efficiency, we value a wider range of behaviors including those that may fail a given task. In doing so we propose that current paradigms aiming to address significant environmental concerns with technological solutions must recognize the reality of failure. Only then can they be undertaken with a genuine equitable intent.

## Self Destructive Robots

subCULTron's ambitious aim to establish a culture of robots in the Venice Lagoon, where they will collect valuable scientific data, faces the challenges of a harsh human polluted environment. These conditions encourage a strong leaning towards highly engineered and robust solutions.

Our time in residence at the A-Life Laboratory in Graz revealed that, the process by which these solutions are achieved, sometimes involves quickly produced test robots, made from easily sourced materials including: jam jars, plastic bottles and other household waste. Mirroring this process, we constructed our own robots from plastic waste (Fig. 1), incorporating plastic bags in their construction—giving them a strong biological appearance and bringing to mind the accidental consumption of plastic; mistaken for a valuable food source by turtles. This consumption is not uncommon with a recent study of seabirds resulting in "debris predicted to have been found in 99.8% of species by 2050" [10]. Ironically, in the lab, our robots began a process of self-consumption with their propellers drawing their tendrils towards themselves where they became entangled; strangling themselves to death. At the time this was considered by our scientific host as an engineering problem for which a solution could be found. It became difficult to communicate our belief that it was in itself an insightful expression of a current environmental situation, where technological solutions provide their own problems. In building robots from plastic

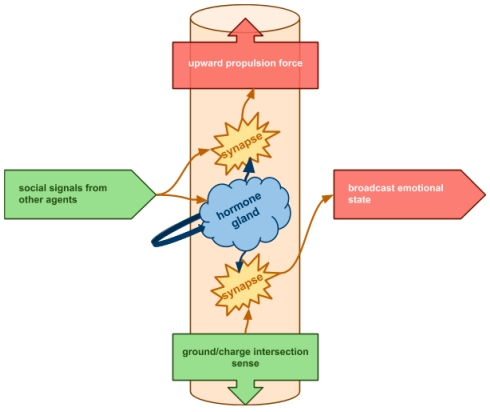
**Fig. 1. boredomresearch underwater plastic waste robot. (© boredomresearch. Photo: boredomresearch.)**

waste there appeared to us a synergy between the problems of human consumption that pollute the environment and the process by which we attempt to provide solutions. This led us to reflect and evaluate on the previously discussed models of artificial hormones and the concept of emotional robotics. With current consideration centered on a use supporting an engineering paradigm we now aim to offer a fuller consideration including the more human capacity for failure.

## Simulating Despondency in Robotics

Modifying and extending the Braitenberg vehicle model with simulated hormones as discussed above, we are now working on a simulation that is inspired by the idea of a culture of marine robots with limited motion capability and a narrow channel for intergroup communication. The simulated robot agents will be faced with a task of navigating their environment, conforming to a similar challenge faced by subCULTron's proposed robot ecology. In essence the agents have two inputs and two outputs connected by an artificial neural network augmented by a simulated hormone gland (Fig. 2). Each agent has the ability to propel itself vertically in a simulated liquid body where it becomes subject to a simulated current. It can also broadcast its emotional state. Input consists of receiving stimuli from other agents as well as from their environment

**Fig. 2. Depiction of a robot agent showing arrangement of network with hormone gland. (© boredomresearch)**




when in contact with the ground. The simulation aims to explore the potential for individual agents to exhibit behavior consistent with an awareness of failure, which will occur when energy levels result in the loss of agency. It is currently unclear if recognition of a failure and subsequent expression of despondency can emerge as a natural product of the system or if it will need to be "engineered" as a solution to acknowledge and incorporate the potential for failure. Ultimately, we aim to introduce a consideration in emotional robotics that respects the fragility of a natural environment subject to high levels of human intervention at increasingly complex levels of sophistication.

What we provide may offer little within a current paradigm centered on increasingly complex technological solutions for increasingly complex problems. It is however consistent with a cultural perspective that precedes the strict constraints of scientific method. It forms part of a continued interaction with science where, in this case, we extend a warm hand from an artistic perspective comfortable with melancholy. In doing so we acknowledge the very human capacity for failure and despondency, for the purpose of fostering an enhanced sensibility for environmental fragility.

**Acknowledgments**

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**References and Notes**

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**1.** *Future Emerging Art and Technology* Workshop, Waag Society, Amsterdam (March 2016), <http://www.featart.eu/>, accessed 14 February 2017.

**2.** subCULTron (2015–2019), <http://www.subcultron.eu/>, accessed 27 February 2017.

**3.** D. Moser, R. Thenius and T. Schmickl, "*First Investigations into Artificial Emotions in Cognitive Robotics,*" subCULTron, Artificial Life Laboratory, Karl Franzens University Graz, Austria (2016) p. 12, <http://zool33.uni-graz.at/artlife/sites/default/files/Paper_MESROB_2016Investigations_Artific._Emo.pdf>.

**4.** Marvin Minsky, *The Society of Mind* (New York: Simon & Schuster, 1986).

**5.** Aaron T. Beck, *Beck Hopelessness Scale* (San Antonio, TX: The Psychological Corporation, 1988).

**6.** S.A. McLeod, "*Psychological Theories of Depression,*" SimplyPsychology (2015), <http://www.simplypsychology.org/depression.html>.

**7.** Vincent van Gogh, *Delphi Complete Works of Vincent van Gogh* (Delphi Classics, 2014).

**8.** T. Ziemke and R. Lowe, *"On the Role of Emotion in Embodied Cognitive Architectures: From Organisms to Robots," Cognitive computation* 1(1), 104–117 (2009).

**9.** E.G. Wilson, *Against Happiness: In Praise of Melancholy* (New York: Farrar, Straus and Giroux, 2008).

**10.** C. Wilcox, E.V. Sebille and B.D. Hardesty, "*Threat of plastic pollution to seabirds is global, pervasive, and increasing,*" Proceedings of the National Academy of Sciences of the United States of America **112**, No. 38 (22 September 2015).

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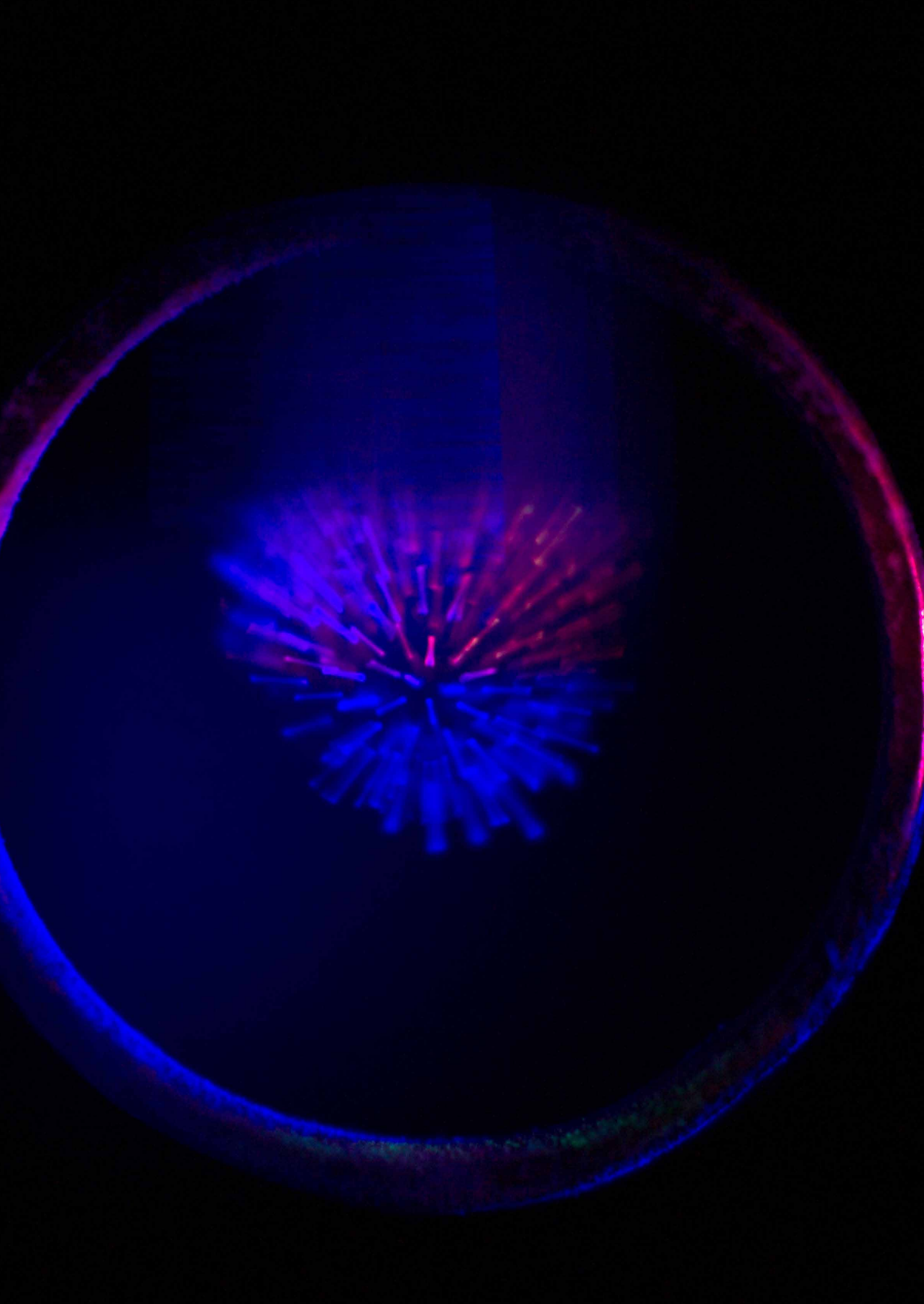
# Evelina Domnitch and Dmitry Gelfand & RySQ

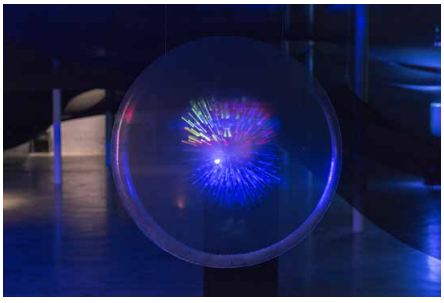
FEAT

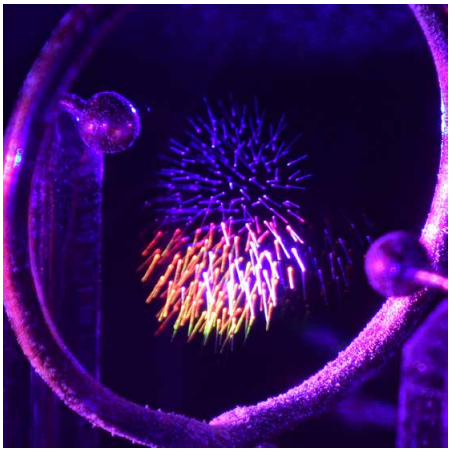


# Evelina Domnitch and Dmitry Gelfand

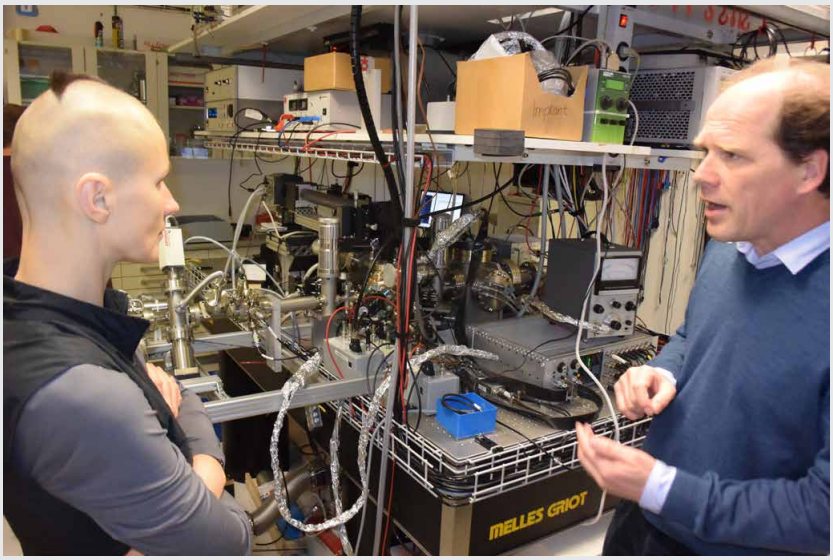
Evelina Domnitch (b. 1972, Minsk, Belarus) and Dmitry Gelfand (b.1974, St. Petersburg, Russia) create sensory immersion environments that merge physics, chemistry and computer science with uncanny philosophical practices. Current findings, particularly regarding wave phenomena, are employed by the artists to investigate questions of perception and perpetuity. Such investigations are salient because the scientific picture of the world, which serves as the basis for contemporary thought, still cannot encompass the unrecordable workings of consciousness.

Having dismissed the use of recording and fixative media, Domnitch and Gelfand's installations exist as ever-transforming phenomena offered for observation. Because these rarely seen phenomena take place directly in front of the observer without being mediated, they often serve to vastly extend one's sensory threshold. The immediacy of this experience allows the observer to transcend the illusory distinction between scientific discovery and perceptual expansion. In order to engage such ephemeral processes, the duo has collaborated with numerous scientific research facilities, including the Drittes Physikalisches Institut (Goettingen University, Germany), the Institute of Advanced Sciences and Technologies (Nagoya), Ecole Polytechnique (Paris) and the European Space Agency. They are recipients of the Japan Media Arts Excellence Prize (2007), and four Ars Electronica Honorary Mentions (2013, 2011, 2009 and 2007).





*Top photo right: Martin Argyroglo for Lieu Unique*
*Ion Hole close-up photo: Dmitry Gelfand*




*Featured in this photograph (on the right) is one of the world's foremost experts in ion traps, Ferdinand Schmidt-Kaler, head of the Cold Ions and Experimental Quantum Information Processing group at Mainz University who helped the artists to build two prototypes.*

## RySQ

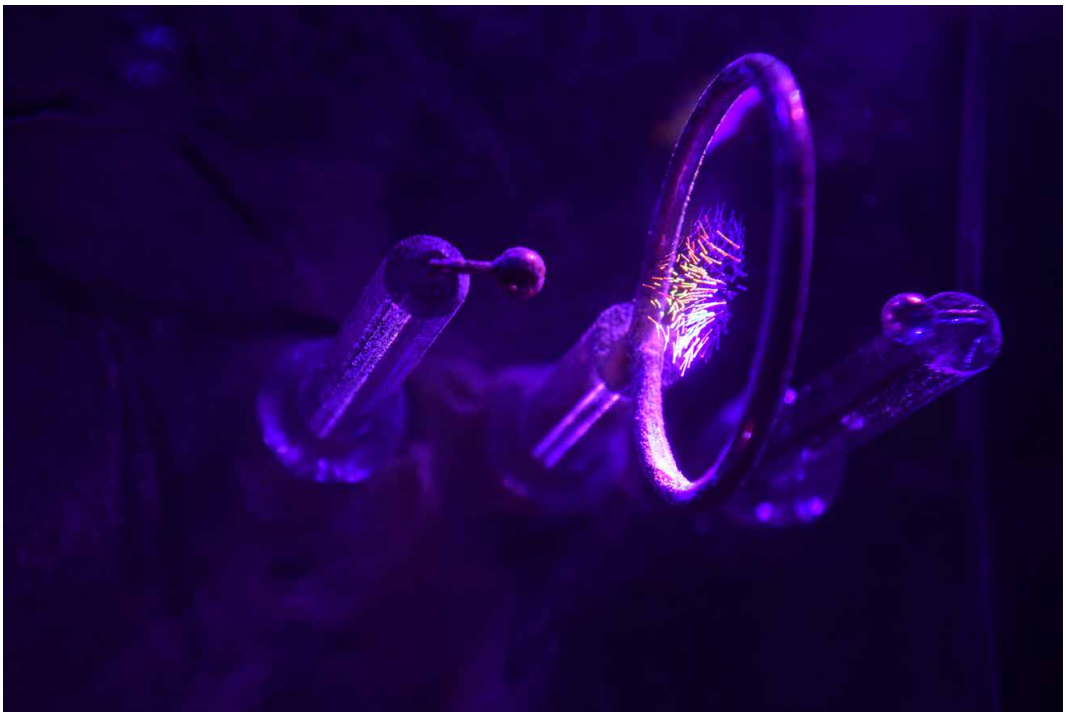
The central objective of the RySQ project is to implement and exploit Quantum Simulators based on Rydberg atoms (called Rydberg Quantum Simulators, RQS), because their outstanding versatility addresses not just one but a whole family of quantum simulations, by exploiting different aspects of the same experimental and theoretical tools. Unique features of laser-excited Rydberg atoms are their long-range van-der-Waals or dipolar interactions, which are simultaneously very large, and entirely controllable by external fields. They offer therefore many different "modes of operation", with either single atom or collective variables, dissipative, monitored and coherent dynamics, short and long range interactions, qubits and multi-level systems. Therefore, RQS provide a powerful toolbox for designing many-body quantum systems for quantum simulation, and to study static and dynamical behaviors, effects of dissipation, transport phenomena, applied to exotic and elusive phases of matter, including frustrated phases, lattice gauge theories, and non-equilibrium dynamics.

Real world systems always involve dissipation, which can even be correlated for Rydberg systems. Besides fundamentally interesting aspects of dissipatively driven phase transitions, one important aspect of the studies is the quantum simulation of quantum magnetism, which underlies many technologically relevant phenomena such as high temperature superconductivity. Another issue is to engineer optimal platforms for preparing quantum many-body states far from equilibrium and to study the transport of excitations in a controlled way. While equilibrium states of physical systems are well understood, the understanding of non-equilibrium phenomena, in particular involving transport of energy, poses a deep challenge to modern science. By direct imaging of the Rydberg atoms, one can monitor the migration of excitations in a spatially and temporally resolved manner, and control their dynamics. RQS will thus shed new light on energy transport in a many-body system coupled to an environment, similar to light-harvesting systems in photosynthesis, which, in turn, might enable the development of novel devices for with enhancing light conversion efficiencies.

# Ion Hole (2016)

In the form of a purely optical (mediumless) projection, Ion Hole unravels the subtle micromotion of charged matter suspended in a ring-shaped ion trap. Inside what is known as a Paul trap (after Wolfgang Paul) are ionized lycopodium spores that repel one another while simultaneously being pushed towards the center of the trap by alternating electric fields. Consequently, the spores self-assemble into an oscillating latticework known as a Coulomb crystal. The inward and outward "breathing" motion of the lattice occurs in phase with the radio wave frequency of the confining electric fields. By illuminating the spores with a laser beam pulsating synchronously and nearly synchronously with the radio frequency, the particles' rapid oscillations can be viewed in slow motion or even made to seem "frozen" in time. The laser illumination also creates a large-scale projection magnifying the spores' ceaseless orbital dynamics.

Among the ongoing philosophical problems in theoretical physics is the inability to describe a quantum system in terms of classical physics. The only way to precisely understand and manipulate quantum phenomena is on their own terms: by means of a quantum simulator - a rapidly evolving methodology initially proposed by Richard Feynman in 1981. Nearly a decade later, Wolfgang Paul was awarded the Nobel Prize for having invented the electrodynamic quadrupole ion trap, which enabled physicists to observe for the first time the quantum nature of an individual atom. Finally, instead of measurements comprising averaged statistical values of large ensembles of atoms, an isolated singular atom could be directly probed. The former approach was based on the classical assumption that all atoms behave in exactly the same way as an average of their statistical behavior. The Paul trap proceeded to become an ideal environment for quantum simulation. Furthermore, the trap's ability to address individual atoms opened a tangible route towards quantum computation: designing logic gates not with bulk matter but rather with discrete properties, such as a single atom's spin, to perform logic operations at unfathomable speeds. The Paul trap has also become a valuable tool in numerous domains besides experimental physics, including chemical analysis, atmospheric science, and aerobiology.



*Ion Hole photos: Dmitry Gelfand*

# Europe's quantum bet

*Manipulating individual atoms opens up huge opportunities for innovation.*

Quantum mechanics is centre-stage in European research, with €1bn set to be invested by the European Commission in a new flagship initiative. Prof. Tommaso Calarco, from the Center for Integrated Quantum Science and Technology of the University of Ulm, in Germany, is among the authors of the Quantum Manifesto, a 20 page document which urges Europe to take action in the field of quantum science.

"We, as the quantum science community of Europe are of course delighted that the European Commission has been responsive to our call," he says, "We feel that with substantial backing and joint efforts Europe-wide, the work carried out across institutes, laboratories and also companies, could really have an impact on our society." The Quantum Manifesto uses surprisingly simple language and features a clear roadmap. "Quantum science is much closer to home that people imagine," adds Calarco, "Even now, when you send a chat message or publish a post on Facebook, you're actually riding on the first quantum revolution. The theoretical advances of the early 20th century, made it possible for industry to deliver a first wave of semiconductor technologies in the Fifties and Sixties. We are now in the middle of the second quantum revolution".

The Quantum Manifesto covers several fields of application, from credit cards and healthcare, to materials. "One of the things that quantum science allows us to do is to multiply and accelerate the pace of calculation or simulation," explains Calarco, "In one of our current research projects, we are trying to manipulate individual atoms, as well as systems built out of them, to simulate the behaviour of fairly complex systems, such as magnetic materials."

"The same approach could be applied to healthcare on simulating how a given molecule could react under certain conditions. More generally, the number of sectors where we could harvest such potential is huge, from chemistry and developing drugs, to increased security, well beyond the levels reached by the current knowledge in cryptography. It goes without saying that to achieve a sufficient capacity of simulation, of the scale we have in mind, we'll need to rely on a much stronger calculation power than we have today." Calarco is collaborating with the Rysq project, supported by the EU 7th Framework Programme Future and Emerging Technologies (FET). Sixteen European research institutes are building a simulator working with the so-called Rydberg atoms.

These atoms are excited into very high energy levels and become extremely responsive to electric and magnetic fields. Because of these characteristics, they hold a huge potential to be used in quantum simulations.

*By Giuseppe Saija*

# The shape of the invisible

*Evelina Domnitch and Dmitry Gelfand's artworks shed (acoustic) light on quantum phenomena .*

The artistic partnership of Evelina Domnitch and Dmitry Gelfand started in 1996 in New York when they were in their early twenties. They were both born in the Soviet Union, Belarus and Russia respectively, and their paths crossed in the US city. About ten years later the artists moved to Amsterdam, where they are based now.
In terms of weirdness, this is nothing compared to their approach to arts, which could be resumed as the almost impossible mission of observing and manipulating the unobservable. "We thought it was necessary to challenge the old notions of object and image," says Evelina Domnitch introducing the subject. "We abandoned solid state artistic practices in favour of directly experiencing the fluid and often weightless state of quantum physicality," adds Dmitry Gelfand.
Exploring the quantum dimension, where the tiniest portions of matter interact according to rules that have little in common with the way we experience the physical world, could expose artists to huge risks. "Instead of abandoning the senses because our perception is incompatible with the quantum world," says Dmitry Gelfand. "We go against the grain to find the observable. We try to calibrate, to take the advantage of the elasticity of our perceptual processes, to tune in to these very odd, very counterintuitive behaviours."

Evelina Domnitch and Dmitry Gelfand deal with vacuum, light, sound, and energy. In their Sonoluminescence installation, they use ultrasound in a vacuum space, to compress micro-bubbles of gas present in liquids, to the point that they collapse, reaching Sun-like temperatures, and emitting light in the shape of the sound that causes this light. "We're exploring a slippery domain called mesoscopic, where quantum behaviour manifests itself on a macroscopic scale," Domnitch explains.

In the Force fields project, they induce the acoustic levitation of a droplet of water, where the effect of gravity is minimized, bringing the droplet to what they define as "harmonic mode isolation".

In Photonic Wind, a laser beam levitates and propels diamond micropowder. Together with Force Fields, the works were at the centre of the Le Vide et la Lumière (Vacuum and Light) exhibition at the Lieu Unique contemporary arts centre in Nantes, France.

"With Rysq we will work at a macroscopic device that will allow us to see charged ions, which in normal conditions, cannot be seen with your naked eye," says Domnicth. "But the way they are trapped, lit and the electro-magnetic fields we can create around them make them visible. This can give the public an idea on how scientist work to build the quantum computing and witness how much they engage with the matter and with the world."

*By Giuseppe Saija*

# TRAPPING THE OBJECTLESS

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*Submitted: 7 March 2017*

**Abstract**

Through the epistemological lenses of quantum theory and phenomenological art, the authors describe their collaborative development of several artworks exploring electrodynamic levitation. Comprising diverse ion traps that enable naked-eye observation of charged matter interactions, these artworks question the murky boundaries of perceptibility and objectification.

## **Part 1** (by Evelina Domnitch and Dmitry Gelfand)

*Experimental physics is the art of observing the structure of matter and of detecting the dynamic processes within it.*
—Wolfgang Paul [1]

Even though our artworks emphatically depart from verbal language and all other forms of symbolic communication, periodically we stumble upon linguistic clues that might elucidate our peculiar inter-scientific, para-philosophical practice. In French, a single word signifies both experience and experiment: *éxperience*. Our endeavors veritably strive to dispel the distinction between these two notions. Is not an experience, but a perceptual experiment? Is it only science's necessity for measurement that distinguishes it from philosophy? When measurements are insufficient, imprecise, or inconsistent with mathematical models, theoretical physicists rely on a philosophical method known as phenomenology—the origins of which stem from Edmund Husserl's phenomenological "Philosophy as a Rigorous Science" [2]. This unlikely trajectory was painstakingly paved by mathematician, physicist and philosopher, Hermann Weyl [3]. Though quite distinct from Husserl's approach, the Weylian phenomenology of contemporary physics inherited Husserl's intuition of a "fluid whole, rather than a set of discrete elements" [4]. Among the leading contributors to unified field theory and the foundations of spacetime geometry, Weyl claimed that Husserl's "phenomenological experiences" were more fundamental than the experience of "elements" or "empirical objects":

> A real thing can never be given adequately, its "inner horizon" is unfolded by an infinitely continued process of ever new and more exact experiences; it is, as emphasized by Husserl, a limiting idea in the Kantian sense. For this reason it is impossible to posit the real thing as existing, closed and complete in itself [5].

Reciprocally, philosophy has always been deeply saturated with scientific inquiry, from cosmogony to psychophysics. Although our methods originate from the phenomenological crossroads of science and philosophy, our path has led to a purely non-verbal phenomenological art of observation, eventually stripped of both measurements and metaphors [6].

Among the ongoing philosophical problems in theoretical physics is the inability to describe a quantum system in terms of classical physics. The only way to precisely understand and manipulate quantum phenomena is on their own terms: by means of a quantum simulator—a rapidly evolving methodology initially proposed by Richard Feynman in 1981 [7]. Nearly a decade later, Wolfgang Paul, Norman Ramsey, and Hans Dehmelt were awarded the Nobel Prize for having invented the electrodynamic quadrupole ion trap, which enabled physicists to observe for the first time the quantum nature of an individual atom. Finally, instead of measurements comprising averaged statistical values of large ensembles of atoms, an isolated singular atom could be directly probed. The former approach was based on the classical assumption that all atoms behave in exactly the same way as an average of their statistical behavior. The Paul trap, as it is now known (after Wolfgang Paul), proceeded to become an ideal environment for quantum simulation. Furthermore, the Paul trap's ability to address individual atoms opened a tangible route towards quantum computation: designing logic gates not with bulk matter but rather with discrete properties, such as a single atom's spin, to perform logic operations at unfathomable speeds. The Paul trap has also become a valuable tool in numerous domains besides experimental physics, including chemical analysis, atmospheric science, and aerobiology.

Years before our collaboration with RySQ (Rydberg Quantum Simulator), we had envisioned creating an artwork with a Paul trap. Our perpetual infatuation with weightlessness has incited various artworks exploring such phenomena as optical levitation in *Photonic Wind* (2013), and acoustic levitation in *Force Field* (2016) and *Sonolevitation* (2007). The prospect of electrodynamic levitation offered an unparalleled means of interaction between alternating electric fields, charged matter, light and nearly negligible (piconewton) gravitational forces [8].

Through FEAT (Future Emerging Art and Technology), we were bestowed the opportunity to collaborate with one of the world's leading ion trap experts, Ferdinand Schmidt-Kaler, head of the Quantum Information Group at Mainz University, and a key figure in the RySQ conglomerate. In but a matter of hours after our arrival in Mainz, Schmidt-Kaler helped us construct the first prototype of our ring-shaped Paul trap. He also recounted a monumental occasion at Rainer Blatt's lab (Innsbruck University), when he observed, along with the Dalai Lama, a single Barium atom glowing inside of an ion trap [9]! The light emitted by the laser-stimulated atom directly reached his eyes through a lens—instead of a metaphor of the light emission captured on a microchip. Schmidt-Kaler and approximately a hundred other witnesses of this miraculous experiment were utterly transfixed. One of the other witnesses happens to be the leader and founder of RySQ, Tommaso Calarco. Together with Schmidt-Kaler and Calarco, we embarked on a mission to transform this single-atom experience into an art installation. Along the way, we have already created two electrodynamic artworks: *Quantum Lattice* (2016) and *Ion Hole* (2016).

Instead of single atoms, in *Quantum Lattice* hollow glass microspheres are levitated to enable naked-eye observation of trapped particle dynamics at room temperature and without a vacuum chamber (to stabilize the trapped sample and prevent any interactions with air molecules, it is customarily laser cooled in an ultra-high vacuum). Between the four poles of a linear ion trap, charged microspheres form a cascading latticework characterized by two simultaneous kinetic regimes: micro-motion occurring in phase with the electric field's oscillation period, outlining symmetric as well as asymmetric square-shaped orbits; and vertically oriented secular orbits, occurring on longer timescales in comparison to the oscillation period,

and continuously pushing particles towards regions of weaker electric fields.

In the form of a purely optical (mediumless) projection, *Ion Hole* unravels the subtle micromotion of charged matter suspended in a ring-shaped ion trap. Inside the trap are ionized lycopodium spores that repel one another while being simultaneously pushed towards the center of the trap by alternating electric fields. Consequently, the spores self-assemble into an oscillating lattice known as a Coulomb crystal. The inward and outward "breathing" motion of the lattice occurs in phase with the radio wave frequency of the confining electric fields. By illuminating the spores with a laser beam pulsating synchronously and nearly synchronously with the radio frequency, the particles' rapid oscillations can be viewed in slow motion or even made to seem "frozen" in time. The laser illumination also creates a large-scale projection magnifying the spores' ceaseless orbital dynamics.

After giving center stage to trapped particles floating in a Paul trap, it is important to keep in mind that the crucial aspect of Paul's invention is the specific three-dimensional configuration of a quadrupolar electric field. This delicate high-voltage experiment conjures a mercurial vision of reality that emerges from the interaction of charges rather than objects. It is impossible to form an object-oriented mental image of rapidly flow-shifting electric fields, and it is equally misleading to objectify a trapped particle incessantly bouncing within these fields—because it is its ghostly charge that is trapped in the electric well. The materiality of the charge carrier hence becomes elusive as it couples with its environs and unveils their complex morphology. Aesthetically reflecting on the conditions and content of such an experiment propels us to tune into the fluid guise of objectlessness [10].

## **Part 2** (by Tommaso Calarco)

The artworks that Evelina Domnitch and Dmitry Gelfand developed in their interaction with the RySQ project under the FEAT program is a particularly limpid example of what their entire opus is doing in an unprecedented and to my knowledge unparalleled way: creating a visual physical experience that touches the heart of the most fundamental aspects of quantum mechanics.

John Bell referred to this as "unspeakable" [11]: the impossibility to attribute locally objective properties to certain quantum systems before they are measured—in other words, the impossibility to speak of such properties before they are observed. The experiment by Alain Aspect [12] that confirmed that impossibility was not only a milestone of last century's science, but also the opening door for the development of quantum technologies such as those the RySQ project is currently pursuing. At the same time it literally left us wordless, in the sense that it guarantees we won't ever be able to experience an intuitive mental image of the physical process that is happening in the experiment—the so-called "objectification," by which a physical systems acquires its objective properties through measurement.

Domnitch and Gelfand's tireless pursuit of art forms avoiding symbolic communication resonates with that very same wordlessness—both in a quite deep philosophical sense and in the very immediate sense of wonder that viewers experience, irrespective of their physical knowledge, when exposed to their art. Their transcending verbal and semantic metaphors, very clearly explained in the text above and even more clearly present in the immanence of their work, hints at the boundaries inherent in the use of words and images to refer to phenomena and objects—a futile attempt when objects, like in quantum mechanics, simply do not exist locally.

For the same reason, perceiving their work can be regarded as a conceptual (non-verbal) metaphor, pointing at the process in which we observe nature, do our best to understand and describe it, manage to do that up to a certain point, but must ultimately give up our pretension to succeed completely.

Ludwig Wittgenstein wrote in the last proposition of his Tractatus: "Whereof one cannot speak, thereof one must be silent" [13]. That is probably true about objectification in quantum mechanics, and perhaps more generally in science. But while you are silent as Wittgenstein prescribes, you may still look, and see, and marvel at what you perceive. This is what Domnitch and Gelfand seem to be doing (and wanting us to do) when they create their work—and this is most certainly what we are doing when we experience it.

**References and Notes**

FEAT is an initiative of eutema GmbH (AT), Stichting Waag Society (NL), and youris.com (BE). It has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 686527 (H2020-FETOPEN-2015-CSA).

**1.** W. Paul, "Electromagnetic Traps for Charged and Neutral Particles," G. Ekspong, ed. *Nobel Lectures, Physics 1981–1990*, (Singapore: World Scientific Publishing Co., 1993).

**2.** E. Husserl, *Phenomenology and the Crisis of Philosophy*, Q. Lauer, trans. (New York: Harper Torchbooks, 1965).

**3.** J. da Silva, "Husserl's Phenomenology and Weyl's Predictivism," *Synthese,* 110: 277 (1997).

**4.** H. Weyl, *The Continuum: a critical examination of the foundation of analysis*, S. Pollard, T. Bole, trans. (Mineola: Dover Publications, 1994).

**5.** H. Weyl, *Philosophy of Mathematics and Natural Science*, O. Helmer, trans. (Princeton: Princeton University Press, 1949).

**6.** E. Domnitch, D. Gelfand, "Art as Rigorous Phenomenology," M. Marangoni ed.. *No Patent Pending* (Brussels: MER. Paper Kunsthalle, 2014).

**7.** R. Feynman, "Simulating Physics with Computers," *International Journal of Theoretical Physics*, Vol. 21, Nos. 6/7 (1982).

**8.** E. Vinitsky, E. Black, K. Libbrecht, "Particle Dynamics in Damped Nonlinear Quadropole Ion Traps," *American Journal of Physics*, Vol. 83, Issue 313–319 (April 2015).

**9.** W. Neuhauser, M. Hohenstatt, P. E. Toschek, and H. Dehmelt, "Localized visible Ba+ mono-ion oscillator," *Physical Review*, A 22, 1137 (September 1980).

**10.** K. Malevich, *The World as Objectlessness*, A. Bouis, trans. (Berlin: Hatje Cantz 2014).

**11.** J. Bell, *Speakable and Unspeakable in Quantum Mechanics* (Cambridge: Cambridge University Press, 1987).

**12.** A. Aspect, P. Grangier, G. Roger, "Experimental Tests of Realistic Local Theories via Bell's Theorem," *Phys. Rev. Lett.* 47, 460 (August 1981).

**13.** L. Wittgenstein, *Tractatus Logico-Philosophicus*, C. Ogden, trans. (New York: Harcourt, 1922).

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# Anna Dumitriu & MRG Grammar

FEAT

# Anna Dumitriu

Anna Dumitriu (1969) is a British artist whose work fuses craft, sculpture and Bio Art to explore our relationship to the microbial world, medicine and technology. She has a strong international exhibition profile, having exhibited at The Picasso Museum, Barcelona (Spain), The Science Gallery Dublin (Eire), The Museum of Contemporary Art (MOCA) Taipei (Taiwan), Waag Society Amsterdam (Netherlands), Art Laboratory Berlin (Germany), and The V & A Museum, London (UK). Her work is held in several public collections, including the Science Museum London (UK) and Eden Project in Cornwall (UK). She works embedded in scientific settings and is artist in residence on the Modernising Medical Microbiology Project at the University of Oxford (UK), a visiting research fellow: artist in residence in the Department of Computer Science at The University of Hertfordshire (UK), an honorary research fellow in the Wellcome Trust Brighton and Sussex Centre for Global Health at Brighton and Sussex Medical School (UK), and a research fellow at Waag Society (Netherlands).

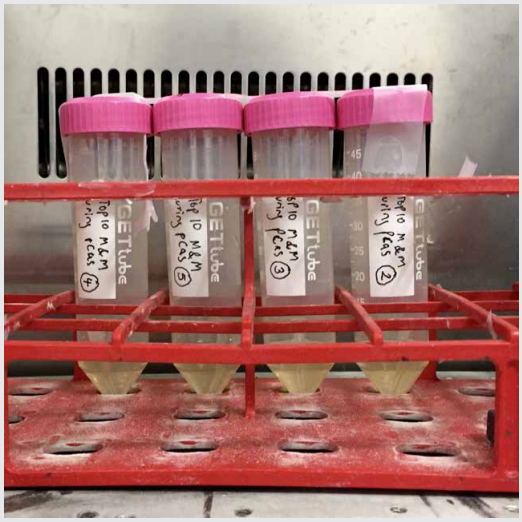
In 2016 she completed a residency at the Liu Laboratory for Synthetic Evolution at The University of California in Irvine (USA) and the resulting artworks were featured in the ground-breaking exhibition “WETWARE” at the Beall Center for Art and Technology in Irvine (USA) curated by Jens Hauser and David Familian. Her work is featured in William Myers significant large format book on Bio Art, entitled “Bio Art: Altered Realities” published by Thames and Hudson in 2016.

Recently Dumitriu has been collaborating with Professor Maggie Smith at The University of York to artistically explore “The Hunt for New Antimicrobials” using synthetic biology. She is the artist partner and on the EU Horizon 2020 funded FET support action FEAT: Future Emerging Art and Technology and is working with the EU FET project MRG-Grammar to investigate the grammar of gene regulation at The Wellcome Sanger Institute, The Weizmann Institute (Israel) and Technion (Israel) through her FEAT residency. Her next challenge is to better understand the biochemistry of DNA and she has commenced a Leverhulme Trust funded art residency with the University of Birmingham focusing on the EU FET project BeyondSeq.

## MRG Grammar

Anna Dumitriu worked in close collaboration with with Dr Sarah Goldberg and Dr Roee Amit to create “Make Do & Mend” at the Synthetic Biology Laboratory for the Decipherment of Genetic Codes at the Technion in Israel. She also gained inspiration working with Dr Sarah Teichmann and her Teichmann Group at the Wellcome Sanger Institute, in the UK, and shadowing researchers Xi Chen, Michael Kosicki and Tomas Pires de Carvahlo Gomes.

MRG-GRammar develops a new strategy for deciphering the regulatory rules of gene regulation using Synthetic Biology, DNA synthesis technologies and high-throughput analysis to generate new types of biological datasets that systematically explore all possible regulatory landscapes. The project will employ its strategy on diverse model organisms from the tree of life from single cell to whole organism: bacteria, yeast, mouse ex-vivo cells, human cell-lines and finally, whole D. melanogaster and mouse embryos. It is expected to lead to a profoundly deeper understanding of the origins of many diseases. The project will also produce models that will serve as a reference in designing and implementing accurate and more controllable synthetic biology devices, with applications in fuel production, healthcare and other industrial fields.

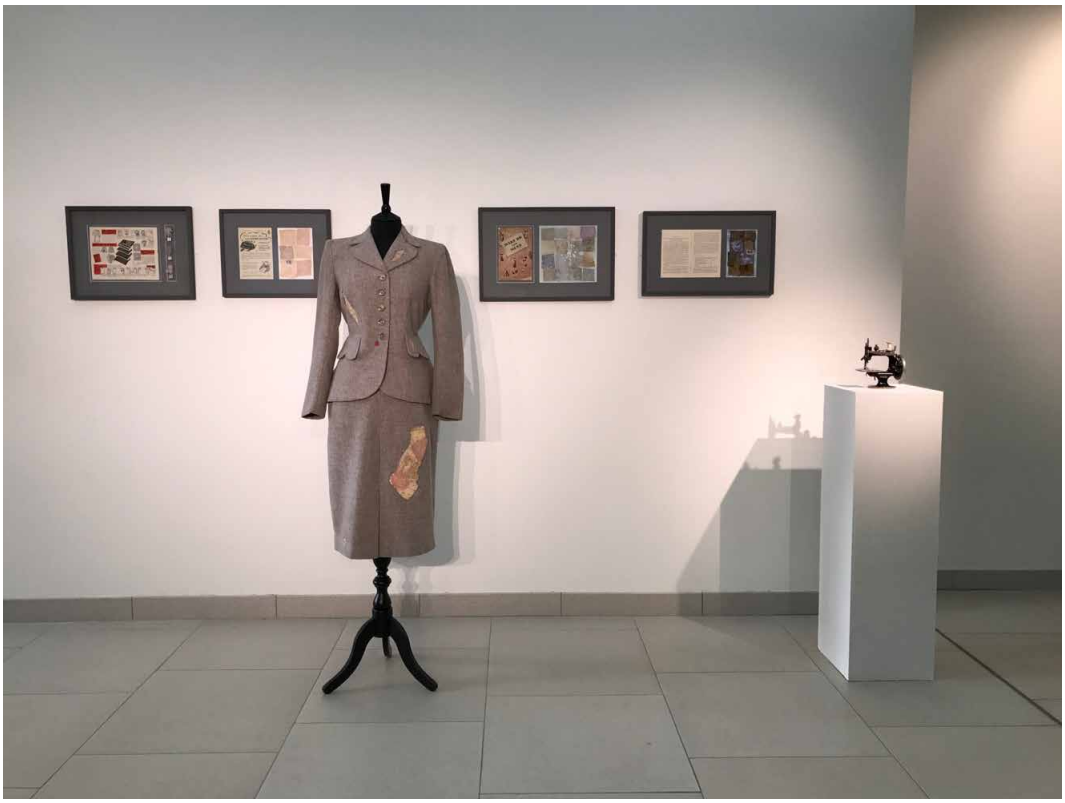


# “Make Do and Mend”

“Make Do and Mend” references the 75th anniversary of the first use of penicillin in a human patient in 1941 and takes the form of an altered antique wartime women’s suit marked with the British Board of Trade’s utility logo CC41, which stands for ‘Controlled Commodity 1941’ meaning that the use of materials has been deemed meet the government’s austerity regulations. The holes and stains in the suit have been patched and embroidered with silk patterned with E. coli bacteria grown using a dye-containing growth medium, forming pink colonies or spots. The genomes of these E. coli bacteria have been edited using a technique called CRISPR to remove an ampicillin antibiotic resistance gene and repaired using a technique called homologous recombination to scarlessly patch the break with a fragment of DNA (converted into ASCII code and then to base 4) encoding the WWII slogan “Make Do and Mend”, which encouraged housewives to repair their clothes during the wartime rationing period.

Ampicillin is part of the penicillin group of beta-lactam antibiotics so in a way it is conceptually and poetically true to say that, with this artistic genomic edit, Anna Dumitriu and her collaborator Dr Sarah Goldberg have used today’s latest technology to ‘mend’ the organism back to its pre-1941, pre-antibiotic era state. Scientifically it is far more complex in that they have used a lab strain of TOP10 E. coli that is very well characterized and has had many other modifications so it will never really be the same as it was in 1941.

We now face a serious global problem of antibiotic resistance as disease-causing bacteria evolve mechanisms to resist our attempts to destroy them, and the wonder drugs, such as penicillin, no longer work. This is in some part because we have misused these drugs since we kick-started the arms race of the antibiotic age in 1941. Our antibiotic stocks have not been protected as the ‘controlled commodities’ they should have been. As a counterpoint today’s governments now seek to control the use of CRISPR but this is difficult because of its accessibility and potential to revolutionize biotechnology.




SINGER

# Make Do and Mend: Exploring Gene Regulation and CRISPR through a FEAT (Future Emerging Art and Technology) Residency with the MRG-Grammar Project

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*Submitted: 7 March 2017*

**Abstract**

This article documents the artistic research the author undertook for her FEAT (Future Emerging Art and Technology) residency. It describes her collaboration with the MRG-Grammar consortium and the creation of an artwork that involved editing the genome of a bacterium using CRISPR to reflect on issues related to antimicrobial resistance, bio-hacking and control. The article explores the author's methodology and describes the benefits of long-term embedded residencies to create artworks that are deeply engaged with emerging technologies with a view to enable the public to access the concepts and implications of cutting edge technologies and scientific research, through an artistic lens.

*Keywords:* CRISPR, BioArt, Synthetic Biology, Antimicrobial Resistance

## Controlled Commodities

"Make Do and Mend" is an installation that references the 75th anniversary of the first use of penicillin in a human patient in 1941 and takes the form of an altered antique wartime dress with the mark CC41, the British Board of Trade's "utility logo" (Fig. 1). The holes and stains in the old dress are patched with silk which has had *E. coli* bacteria grown onto it using a dye-containing growth medium. The genomes of the bacteria have been edited using a cutting-edge technique called CRISPR to remove an antibiotic resistance gene accompanied by homologous recombination to scarlessly repair the break with a fragment of DNA encoding the phrase "Make Do and Mend" [1]. CRISPR/Cas9 is a revolutionary gene editing tool that enables researchers to cut DNA accurately at designed positions, thereby facilitating the editing of genomes of living organisms.

We currently face the serious global problem of antibiotic resistance that requires us to protect our stocks of antibiotics and use them in a highly controlled way. The World War II CC41 utility mark showed that goods such as clothes and furniture met the UK government's austerity regulations, meaning literally "controlled commodity 1941." Ironically, then, penicillin and the antibiotics that came after really needed to be far more of a controlled commodity than dining sets, dresses and other goods that received the CC41 utility mark. The issue of control is highly relevant not only to commodities and antibiotics, but also to emergent technologies: there is a lot of discussion today about the regulation of the recently discovered gene-editing technique CRISPR/Cas9 [2], as it has the potential to be used to edit bacterial genomes, viruses and even human genomes and, in some cases, can even be used in citizen science laboratories.

**Fig. 1. "Make Do and Mend" installation view at LifeSpace Dundee (© Anna Dumitriu. Photo: Anna Dumitriu.)**

## Exploring the Decipherment of Genetic Codes

I worked with Drs. Sarah Goldberg and Roee Amit at the Synthetic Biology Laboratory for the Decipherment of Genomic Codes at the Technion in Haifa, Israel. The lab is the lead coordinator on the MRG-Grammar project [3] which aims to devise a new strategy for deciphering the rules of gene regulation. Using synthetic biology, DNA synthesis and high-throughput analysis, the project aims to generate new types of biological datasets that systematically explore all possible regulatory landscapes.

## Working Hands-on with CRISPR/Cas9 in the Lab

I learned hands-on to edit the genome of the TOP10 *E. coli* strain to remove an ampicillin (a penicillin related antibiotic) resistance gene which was part of the bacterium's genome (having previously been inserted into it) using CRISPR/Cas9, thereby literally mending the bacterium in the same way that the dress is mended with the bacteria-stained cloth.

## Editing *E. coli* Using CRISPR/Cas9 for Art

Ampicillin is part of the penicillin group of beta-lactam antibiotics so in a way it is conceptually and poetically true to say that, with my artistic genomic edit, I have used today's latest technology to 'patch' or 'repair' the organism back to its pre-1941, pre-antibiotic age state [4]. But scientifically it is far more complex in that I used a lab strain of *E. coli* that is very well characterized and has had many other modifications so it will never really be the same as it was in 1941.

Dr. Goldberg and I cut out a short region of the pspG operon: CAAATTCACCACGCCCTGCGCACCGTCGCGGG GCGTTTTGCTGTTAAATCAATAGATTATTTTTG and replaced it with a repair fragment of DNA in the form of an encoded phrase: "Make Do and Mend" converted via ASCII code to base 4 to align to the ATCGs of the DNA nucleotides, making: CATCCGACCGGTCGCCAGAACACACGTTA GAACGACCGTGCGCAAGAACATCCGCCCGTGCGCA.

## Introducing Top10 *E. coli* Make Do and Mend

The resulting TOP10 *E. coli* Make Do and Mend strain was grown onto silk squares placed in Petri dishes on selective *E. coli* chromogenic agar (Oxoid Limited), a dye containing solid growth media (made from seaweed jelly) that causes the bacteria to grown colorful colonies, with the help of Dr. Heather Macklyne at the University of Sussex. The silk squares were then sterilized in order to be made safe, enabling me to stabilize and remove the genetically modified bacteria from the lab and work with them to repair the CC41 dress. I also received additional collaborative support in the UK from Dr. John Paul, Kevin Cole, Dr. James Price, and Dr. Nicola Fawcett from Modernising Medical Microbiology, and Dr. Rob Neely from the University of Birmingham.

Although what we have done here would not work as a therapy in humans, the piece is very much about exploring the technology and highlighting its future potential. For one thing, I have found that editing bacteria using CRISPR is actually not at all straightforward, and was intensely time-consuming and laborious, although it's a huge improvement on past techniques and is developing quickly. MRG-Grammar co-ordinator Dr. Roee Amit used the metaphor of a minefield to describe the difficulties of editing bacteria, in conversation with me. However, the scientific community is genuinely at a watershed in the research and we now have significant insights into how genes are regulated but we are still a long way from full understanding. So, in a way the artwork I have created asks if new technologies such as CRISPR will enable us to 'mend' issues that past scientific innovations have inadvertently created, such as antibiotic resistance (albeit having saved countless lives) or create further issues. They certainly are enabling us to understand how DNA works better.

## Florey and Chain Were Bio-Hackers

CRISPR is a very exciting technology and of great interest to those involved in the bio-hacking and maker culture scene. These biohacking approaches have a strong resemblance to Howard Florey and Ernst Chain's wartime penicillin trials at The University of Oxford, for which they won a Nobel Prize alongside Alexander Fleming. In 1941 there was a huge lack of availability of proper lab equipment and they made do and mended their own lab equipment for fermenting the famous mold from biscuit tins and lidded hospital bed pans. My "Make Do and Mend" project is strongly inspired by Oxford Museum of The History of Science's exhibition "Back From The Dead," which tells the story of the development of penicillin in Oxford, and includes a huge range of important historical objects as well as my growing participatory artwork "Ex Voto" [5] created in collaboration with Dr. Nicola Fawcett (Oxford University) and Professor Maggie Smith (University of York), with contributions from the MRG-Grammar consortium partners.

## Make Do and Mend

"Make Do and Mend" was originally a leaflet published by the British Ministry of Information in 1943 during World War Two. It advised readers on how to be fashionable under clothes rationing. It contained economical patterns and advice on upcycling old clothes. The leaflet became a vital handbook for housewives. Specifically, readers were given hints on creating attractive "decorative patches" to mend holes in worn out garments clothes. An updated version was recently republished to enable families to cope with economic austerity [6].

## The FEAT Project Residency Methodology

My joint role within the FEAT (Future Emerging Art & Technology) project was as the artist partner in helping to conceive and organise the programme, and also as a pre-selected participating artist. I was involved in creating the ethos of FEAT and in setting out the methodology for the residencies. FEAT was funded as a Horizon 2020 FET (Future Emerging Technology) Support Action of the European Union [7].

Our methodology aims to develop in-depth collaborations through long-term embedded residencies shadowing researchers and working hands on in the lab to understand the research, methods and processes [8]. This methodology was based on a great deal of past experience of working in science settings, particularly my 14-year collaboration with microbiologist Dr. John Paul and with Modernising Medical Microbiology [9]. The FEAT consortium (Eutema, Waag Society and Youris) were able to raise generous funds for artists to undertake residencies of up to nine months and to absorb as much as possible from the opportunities. It is intended that the outcomes of the FEAT residencies should somehow serve to engage the public in new technologies, and in the case of my work, involves very diverse audiences in issues around cutting edge technologies.

The FEAT project concept also builds on my work as lead artist on the Creative Europe supported *Trust Me, I'm an Artist* project, with ethicist Professor Bobbie Farsides and Waag Society, which explores the ethical implications of artists, particularly bioartists, in labs [10]. In my FEAT residency, I used the raw materials of the MRG-Grammar consortium's research to create artworks and develop ideas for workshops for participants of all ages and backgrounds. I worked with controversial CRISPR technology and combined this with using more traditional craft and fine art techniques such as stitch and sculpture, which in my experience helps draw in audiences to the stories I am trying to tell though an aesthetic approach. The collaboration with MRG-Grammar has enabled me to build on some of my recent projects focusing on whole-genome sequencing and synthetic biology and take those ideas further. I will continue to work with the Amit lab and take the research forward. I have also explored the research of other consortium partners at the Teichmann Lab at the Wellcome Sanger Institute, Cambridge, UK and at the Segal Lab at the Weizmann Institute, Tel Aviv, Israel, and will use that research to develop further artworks. I also have plans to work next with a penicillin-resistant *Staphylococcus aureus* bacterium from my own body.

**References and Notes**

FEAT is an initiative of eutema GmbH (AT), Stichting Waag Society (NL), and youris.com (BE). It has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 686527 (H2020-FETOPEN-2015-CSA).

**1.** <http://www.normalflora.co.uk>.

**2.** <https://www.addgene.org/crispr/guide>.

**3.** <https://www.mrg-grammar.eu/>.

**4.** <http://www.mhs.ox.ac.uk/exhibits/back-dead-demystifying-antibiotics>.

**5.** <http://www.mhs.ox.ac.uk/backfromthedead/exhibition/ex-voto>.

**6.** <http://www.bl.uk/learning/timeline/item106365.html>.

**7.** <http://featart.eu>.

**8.** Creative Disturbance: <http://creativedisturbance.org/podcast/bacteria-as-an-art-medium-meeting-with-anna-dumitriu-eng/>.

**9.** <http://modmedmicro.nsms.ox.ac.uk/art/>.

**10.** Dumitriu Anna, Farsides Bobbie, *Trust Me, I'm an Artist. Towards an Ethics of Art and Science Collaboration,* Blurb Edition, 2014.

4

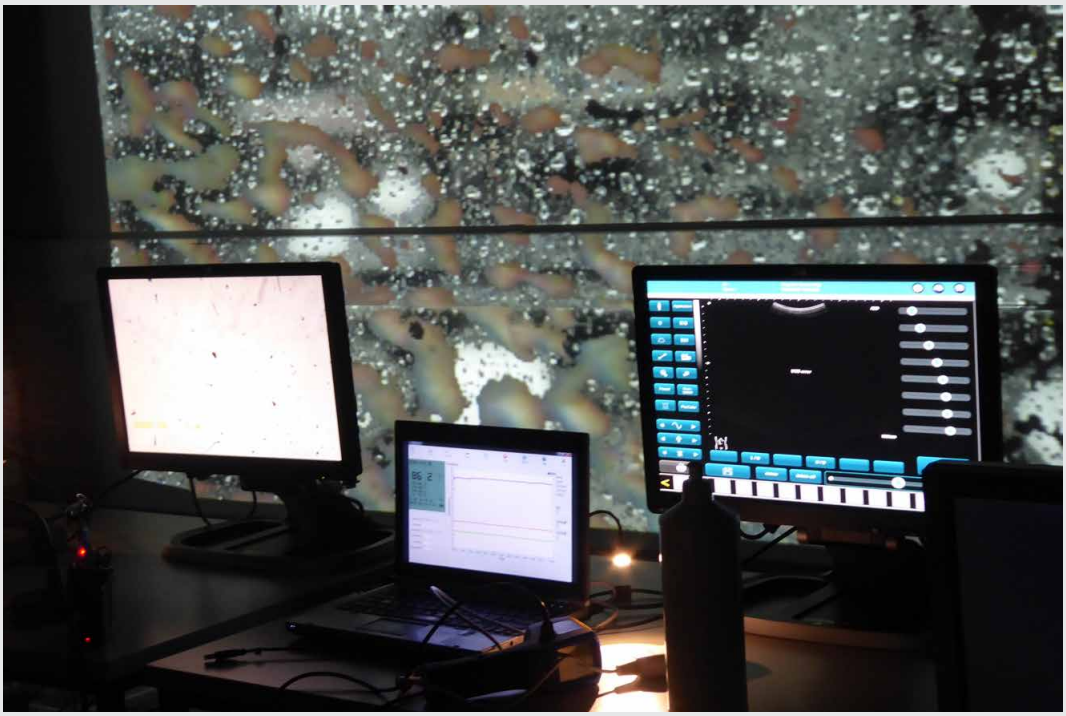
# Miha Turšič and Špela Petrič & INTERTwineE

FEAT

# Miha Turšič and Špela Petrič

Miha Turšič (1975) finished industrial design studies at the Academy of Fine Arts in Ljubljana in 1998. He began his professional career as a digital visualizations designer at the digital production house ARXEL TRIBE. In 1998, he co-founded the design company ASOBI, who were proclaimed designers of the year in the Lighting category by the international design magazine I.D. Since 2005, he has directed his research towards art and design in zero-gravity environments. In his career he co-founded several institutions in field of research, development and art and is actively involved in space culturalization and designing zero-gravity dwellings. Along with Dragan Živadinov and Dunja Zupančič, he has been the main protagonist of Posgravity Art, which includes the 50-year multimedia theatre project Noordung::1995-2045. In 2006 he constructed a memorial centre in Vitanje dedicated to the pioneer of space technology, Herman Potočnik Noordung. Since 2012 he has been developing the Cultural Space Programme (KSEVT), a bridge between artistic, academic and space institutions. As of 2017 he is employed at the Waag Society, Amsterdam, as a cultural program developer.

Špela Petrič, BSc, MA, PhD, is a Slovenian new media artist and scientific researcher currently based in Amsterdam, NL. Her artistic practice combines natural sciences, new media and performance. While working towards an egalitarian and critical discourse between the professional and public spheres, she tries to envision artistic experiments that produce questions relevant to anthropology, psychology, and philosophy. She extends her artistic research with art/sci workshops devoted to informing and sensitizing the interested public, particularly younger generations. In particular, she is interested in all aspects of anthropocentrism, the reconstruction and reappropriation of scientific knowledge in the context of cultural phenomena, living systems in connection to inanimate systems manifesting life-like properties, and terRabiology, an ontological view of the evolution and terraformative process on Earth. Her work has been shown at many festivals, exhibitions and educational events in Slovenia and around the world (Abandon Normal Devices (UK), Gamerz (FR), Touch Me Festival (CRO), Pixxelpoint (IT), European Conference on Artificial Life (IT), Playaround (TW), Harvard (ZDA), Ars Electronica (AT), National Center for Biological Sciences (IN), HAIP (SI), Arscope (GER), Mutamorphosis (CZ)).



## INTERTwinE

Dr George Beckett is a Project Manager at EPCC, University of Edinburgh, managing a wide range of software-engineering projects with commercial and academic partners, including roles in international collaborations such as the Framework 7-funded Fortissimo cloud-computing project, the Large Synoptic Survey Telescope, and the ESFRI project ELITRANS. During 2012--2015, Beckett was seconded to the Pawsey Supercomputing Centre in Perth, Australia. As Deputy Director of Pawsey, he was responsible for promoting uptake of (petascale) supercomputing facilities and developing the computational-research community in Australia, as well as growing Pawsey's capabilities to support the significant Australian radio-astronomy community (most notably the Square Kilometre Array telescope and its precursors). Beckett's academic background is in computational mathematics: he has an Honours degree in mathematics from New College, Oxford and a Ph.D. in Computation Mathematics from the University of Strathclyde, Glasgow. He has significant experience of a range of scientific-computing areas, include: high-performance computing; cloud computing; data-intensive research; and accelerator programming, alongside domain expertise in astronomy, industrial modelling, and numerical linear algebra. Beckett is the Project Manager for the Horizon 2020 FET-HPC project INTERTWinE, whose main focus is on interoperability between programming models for large-scale HPC systems.

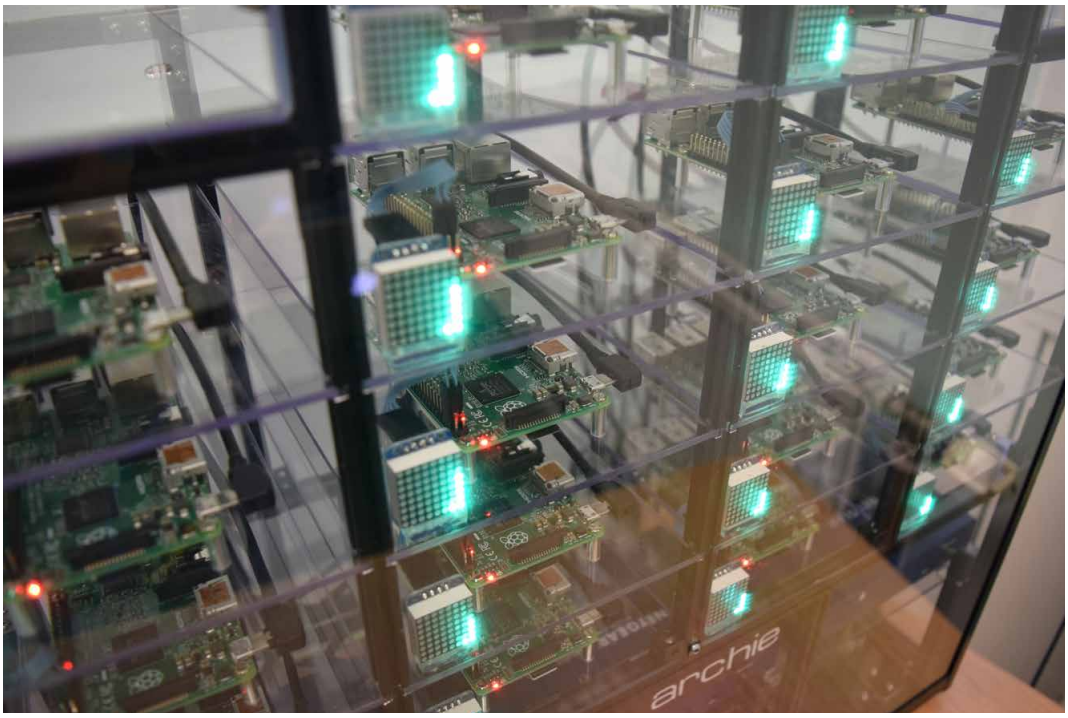
Dr Nick Brown is an applications consultant at EPCC with research interests in parallel programming language design, compilers and runtimes. He has worked on a number of large scale parallel codes including developing MONC, an atmospheric model used by the UK climate & weather communities. He is also interested in micro-core architectures developing ePython, a very small memory footprint Python interpreter with parallel extensions, for many core, low memory chips. Nick is a course organiser on EPCC's MSc in HPC course, as well as supervising MSc and PhD students.

# Becoming.a(thing)

Artists Špela Petrič and Miha Turšič undertook the challenge of understanding and manifesting the artistic potential of high performance computing (HPC). As a result of the collaboration with FET-HPC we developed a concept liberated from the complex computational technicity to underscore the (un) intentional construction of meaning by algorithmic agencies. The performance presents a congress of actors sensing, interrogating, and interrupting each other, thereby producing an excess of relation, interpretation and translation. The heterogeneous congress performs an expulsion of imposed (anthropogenic) meaning, substituted by authentic, autogenic sense and non-sense.

Bits and bytes are organized in the space and shape of contemporary concepts; they are the result of our cultural achievements, biases, future projections, ideologies and policies. Moreover, like a cybernetic loop, they feed back (and forward) into the very space they emerge from, sometimes disrupting but more often reinforcing notions that generated them in the first place. By their action algorithms produce intended and unintended meaning; more appropriately, a sense of the world, and a non-sense, which is different from that created by a human agency.

The performance consists of several objects – an ultrasound scanner, the SD card, articles, books, image analysis and speech-to-text algorithms, human cells, photographs, computer programmers, the ARCHER supercomputer and the artists attempting to interpret each other's signs, enacting a multitude of semiotic relations which emerge at the other-than-human level. The so-called congress presents an ontological slippage in agency in the vein of new materialisms, acknowledging the extensive production of sense amongst the algorithmic and non-algorithmic objects, which reside in the various forgotten layers of our experience. By its action it also produces an excess of signifiers, which dwarf the discrete algorithmic categories and propose a form of resistance to algorithmic 'objectivity' and its totalizing effects.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# BECOMING.A(THING): AN ARTISTS' PERSPECTIVE ON HIGH PERFORMANCE COMPUTING

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*Submitted: 7 March 2017*

**Abstract**

The article summarizes the process and outcome of the Future Emerging Art and Technology residency during which new media artists Špela Petrič and Miha Turšič undertook the challenge of understanding and manifesting the artistic potential of high-performance computing (HPC). As a result of the collaboration with FET-HPC the artists developed a concept liberated from the complex computational technicity to underscore the (un)intentional construction of meaning by algorithmic agencies. The performance presents a *congress of actors* sensing, interrogating and interrupting each other, thereby producing an excess of relation, interpretation and translation. The heterogeneous congress performs an expulsion of imposed (anthropogenic) meaning, substituted by authentic, autogenic sense and non-sense.

*Keywords:* performance, algorithm, high-performance computing, sense, semiotics

Future Emerging Art and Technology (FEAT) is a program, which embeds artistic research into cutting edge technological development and scientific knowledge production. As a subdivision of the Future Emerging Technologies (FET), FEAT acknowledges the immense impact that sites of technological innovation have on various levels of society, from facilitating biopower's grip on each individual to influencing decisions in geopolitical processes. By enabling collaborations between artists and scientists, FEAT reflects ever-growing institutional and financial support of interdisciplinary practices, which expand goal-driven applications of technology and to an extent counteract the utilitarianism increasingly penetrating science.

During the six-month residency we collaborated with Dr. George Beckett and several scientists of the high-performance computing (FET HPC) consortium, which connects scientific and commercial partners within the European Union dealing with upscale parallel computation (high throughput complex simulation, deep learning, data mining and algorithmic prediction). The field of HPC itself is currently undergoing a transition, navigating between two mutually exclusive strategies: continuing along the path of incremental increase in speed or focusing on ease of use. Because a continued increase of computational power necessitates ever more specialized programming languages suited to the particular architecture of each supercomputer, it in turn limits accessibility. Moreover, the HPC community is searching for ways to better connect to industry and to implement big data into research.

As complete novices to the field, the residency presented us with a unique opportunity to visit various HPC centers and talk to the scientists and engineers on site. In July 2016 we started with the European Centre for Medium-Range Weather Forecasts in Reading (UK) where Dr. Peter Bauer (ESCAPE FET project) introduced us to weather forecast supercomputing and guided us through the infrastructure, computer room, data storage and support facilities. During the same month we also visited the IRISA center in Rennes (FR) where Dr. Francois Bodin (EXDCI FET project) talked to us about to the scientific method of simulation, different applications and in particular about the organization and structure of HPC institutions, including their wider political ecosystem. He also invited us to the EXDCI conference in September in Barcelona (ES) to experience the policy making process in action. There we had the opportunity to present the FEAT initiative to the representatives from all FET HPC projects and institutions. The visit was a fruitful exchange of perspectives on HPC, its infrastructure, computation and the sociocultural footprint of algorithmic production. On that occasion we also had a tour of the Barcelona Super Computer MareNostrum that is highly photogenic as it is located inside a decommissioned church. It was surprising that despite its centuries old appearance the church was built less than fifty years ago—and is as such a simulation of sacral architecture.

The conceptual development of the artwork took place in the EPCC center in Edinburgh (UK) where we concluded the final phase of our research, working on experiments, artistic interventions and first prototypes. We were provided with a space to work and the availability of experts from all required fields of science and engineering. We will outline a few of the many threads we pursued.

Coming from the fields of biology, bioart and art in outer space, we were initially interested in HPC's energy metabolism and the materiality of supercomputing. We wanted to understand the ecological niche that algorithmic processes occupy in our ecosystems, hoping to root the abstract flow of information in its ultimately material manifestation. What possible computation is so important that we as a society commit a whole power station to its operation? (This premise turned out to be somewhat of an exaggeration; e.g. the UK national HPC service ARCHER uses up to 2 MW [1], compared to the average coal power plant output of 2000 MW.) The answer was underwhelming—most of Europe's supercomputers are employed to run simulations of scientific experiments, the so-called third pillar of science (beside observation and experimentation), which obfuscates their connection to society at large. They do, however, fulfill a political role, as having the fastest computer helps to establish a position of power amongst nations [2].

At the EPCC we conducted a pataphysical experiment [3]: considering the huge impact (big) data has on our lives, we wanted to measure its weight. Using a highly accurate balance at the Department of Geosciences, University of Edinburg, we weighed an SD card, the first time filled with all zeros (the state we dubbed "empty"), then later with random zeros and ones written to it (Fig. 1). The difference was 0,0042 mg, but the interpretation of the results is highly contestable, as we couldn't figure out which state of the SD card was actually full. The experiments were cut short due to the scientific senselessness of our endeavor.


**Fig. 1. Weighing data. (© Špela Petrič and Miha Turšič. Photo: Špela Petrič and Miha Turšič.)**

Another aspect that piqued our interest was the subjectivity in computer science. The programmers we spoke to readily admitted to a personal signature in the codes, reflecting the proficiency and skill of their author, but moreover they pointed to "subjectivity" as a result of the process of deliberation with the client. During their development, all algorithms are provisional, but only what is deemed undesirable within the scope of the aim is addressed and modified. This implies that it is difficult to ascribe responsibility for adverse effects algorithms might have [4]. Further, with the use of deep learning and neural networks a subjectivity that is a contingent property of the algorithm itself emerges. Often these algorithms present a black box that can only be monitored by observing input and output data, thus acquiring an intrinsic agency much like the organisms used in biotechnology.

Finally, we wanted to understand the openness of algorithmic governance to public initiatives. We were pleased to discover two recent big data projects (Perth Big Data Week and GovHack in Australia) that organized public access to governmental datasets based on which the skilled public could algorithmically extract information. However, as explained to us by San Francisco developer Ben Werdmuller, the Silicon Valley perspective sees individuals more likely to partake in algorithmic governance through personal assistants, which will be proprietary and will ensure the maximum customization of our consumer needs. In the case of UK's ARCHER, we identified a slump in computer usage during the holidays and see this as an opportunity to approach the otherwise scientifically dedicated supercomputer with proposals to run algorithms that might be interesting to the wider society.

Taken together, our research pointed to an objective limitation in the possible artistic use of supercomputing due to the specialized nature of programming required as well as the difficult access and substantial cost associated with running a program on the machines. We wanted the art piece to reflect these cross-disciplinary struggles and simultaneously speak about the semantics, which underlie algorithms as we found the meaning-making process—with misunderstandings, ill communication and decontextualisation—to be a pivotal aspect through which the social, cultural and computational spheres intertwine.

Bits and bytes are organized in the space and shape of contemporary concepts; they are the result of our cultural achievements, biases, future projections, ideologies and policies. Moreover, like a cybernetic loop, they feed back (and forward) into the very space they emerge from, sometimes disrupting but more often reinforcing notions that generated them in the first place. By their action algorithms produce intended and unintended meaning; more appropriately, a sense of the world, and a non-sense, which is different from that created by a human agency. The ability of living systems to engage in an adaptable interpretation of signs (the so-called semiotic freedom [5]) extends to objects and nonliving agencies as the sense producing technological mentality [6]. Algorithms can be looked upon as abstract machines in the production sense, which bathe us in their open non-operability [7].

The performance consists of various categories of objects—an ultrasound scanner, the SD card, articles, books, image analysis and speech-to-text algorithms, human cells, photographs, computer programmers, the ARCHER supercomputer and the artists—attempting to interpret each other's signs, enacting a multitude of semiotic relations which emerge at the other-than-human level (Fig. 2). The so-called congress presents an ontological slippage in agency in the vein of new materialisms, acknowledging the extensive production of sense amongst the algorithmic and non-algorithmic objects, which reside in the various forgotten layers of our experience. By its action it produces an excess of signifiers, which dwarf the discrete algorithmic categories and propose a form of resistance to algorithmic 'objectivity' and its totalizing effects. The artwork is a cross-entity machine within which the human is just another thing.

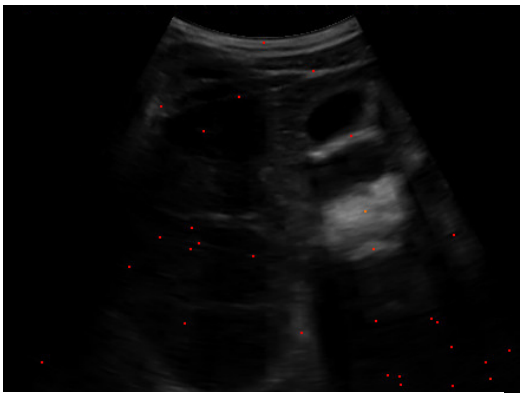

**Fig. 2. Stars and galaxies identified in an ultrasound image of the human body. (© Špela Petrič and Miha Turšič. Photo: Špela Petrič and Miha Turšič.)**

**Acknowledgments**

We would like to thank the whole FET-HPC community for their kind contribution and in particular Dr. George Beckett and Nick Brown from EPCC, Edinburgh, Dr. Peter Bauer from ECMWF, Reading and Dr. Francois Bodin , Irisa, Rennes, for inspiring conversations and the review of this article.

**References and Notes**

FEAT is an initiative of eutema GmbH (AT), Stichting Waag Society (NL), and youris.com (BE). It has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 686527 (H2020-FETOPEN-2015-CSA).

**1.** Jeffrey S. Vetter, Contemporary High Performance Computing: From Petascale toward Exascale (Chapman & Hall/CRC Computational Science, 2013).

**2.** Top 500 List, <www.top500.org/imprint/>, accessed 1 January 2017.

**3.** Jarry Alfred, *Gestes et opinions du docteur Faustroll, pataphysicien: roman néo-scientifique; suivi de Spéculations* (Paris : E. Fasquelle, 1911).

**4.** MEP Marietje Schaake, Algorithmic accountability and transparency in Digital Economy, <alde.livecasts.eu/algorithmic-accountability-and-transparency-in-the-digital-economy>.

**5.** Jesper Hoffmeyer, Semiotic freedom: an emerging force (Cambridge University Press, 2014).

**6.** Erich Hörl, *The artificial Intelligence of sense: The history of sense and technology after Jean-Luc Nancy* (by way of Gilbert Simondon), *Parrhesia*, Number 17, 2013, 11–24.

**7.** [6].

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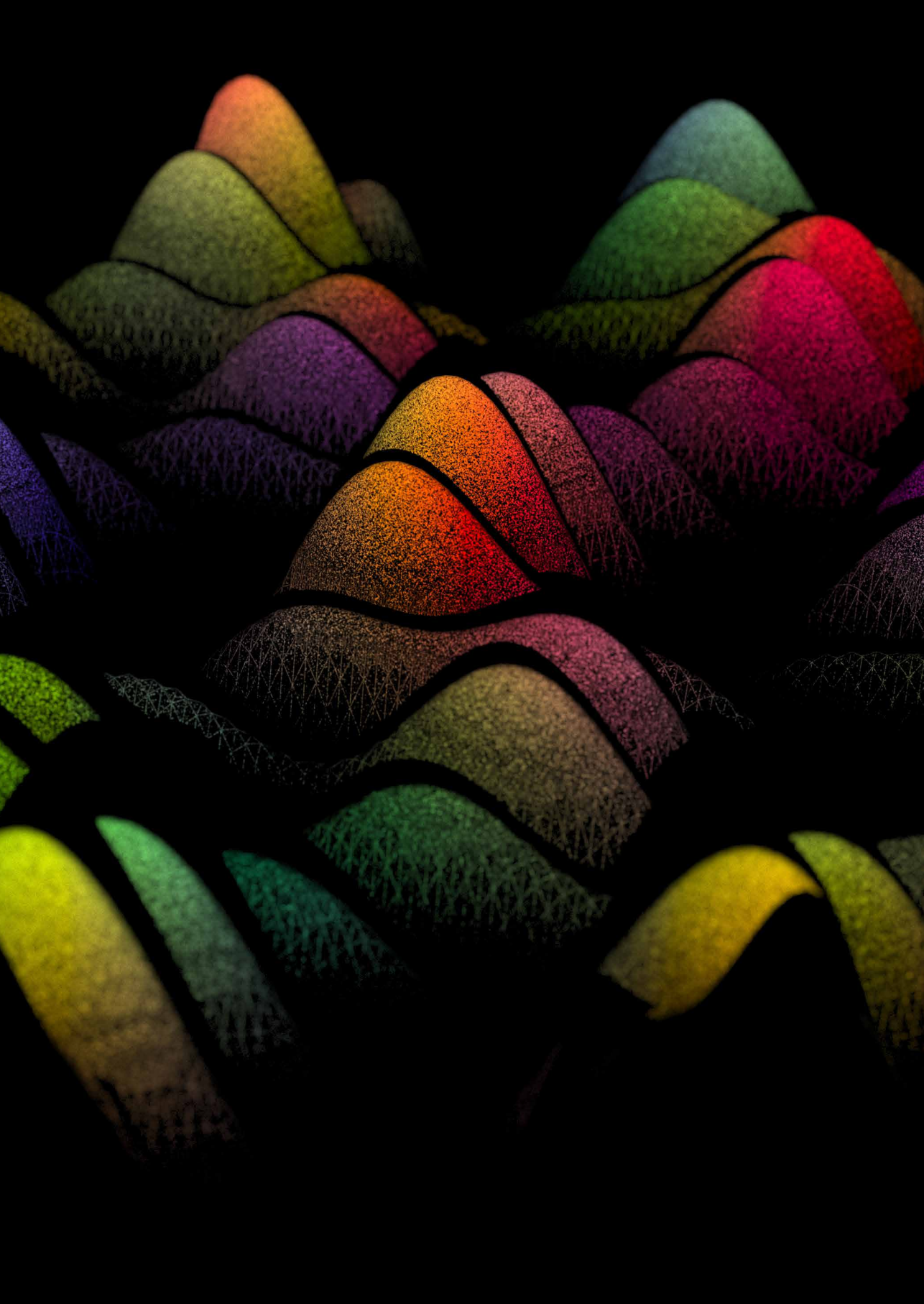
# Semiconductor & QuProCS

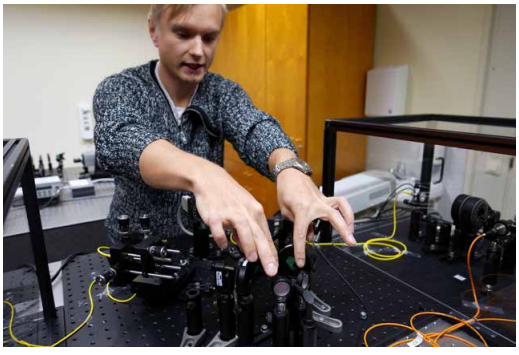
FEAT

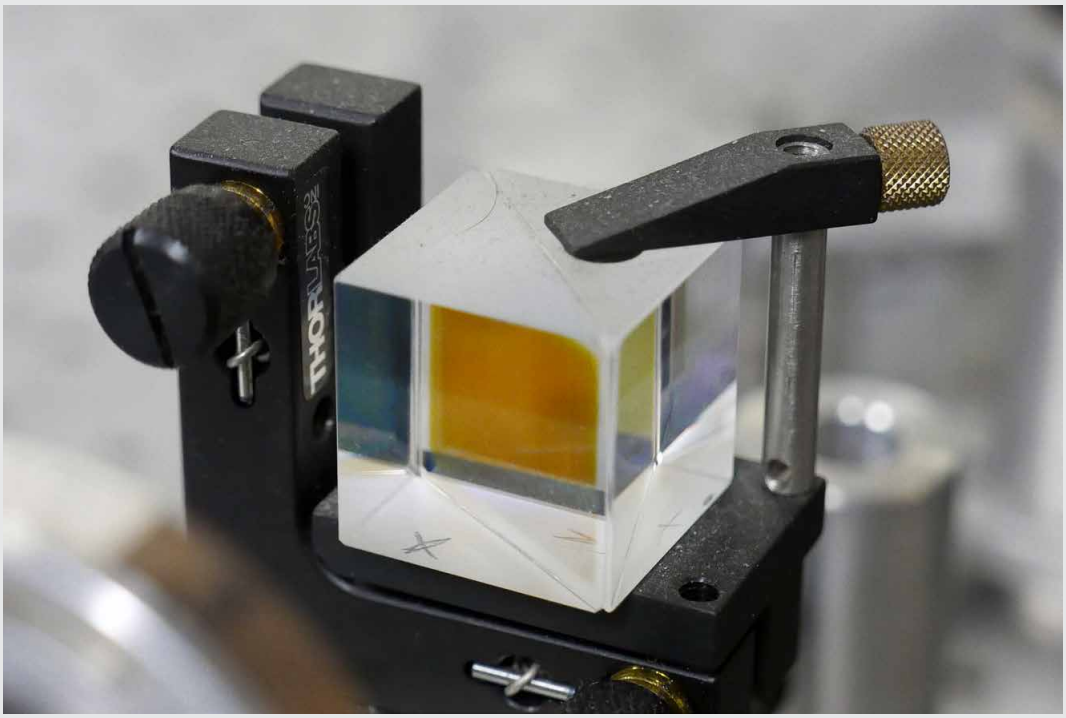


# Semiconductor

Quantum physics has until recently mostly been understood theoretically and mathematically rather than through direct observation or simulation. The idea to build a quantum simulator was first proposed by Richard Feynman in 1981, and a form of one can be observed in the left hand gallery in the work of Evelina Domnitch & Dmitry Gelfand. Showing in the right hand gallery, following on from their residency with particle physics laboratory at CERN – the site of the Large Hadron Collider – artist group Semiconductor chose to work with the FET project QuProCS (quantum probing for complex systems), who work on the problems of the emulation of quantum phenomena. It is often said that in the field of quantum physics it is impossible to measure something without affecting it; the very measurement techniques – such as probes – destroy the properties from which the simulation stems. (Consider what happens when you poke at a soap bubble to see how fast it moves.)

Initially, Semiconductor deliberately take an outsider's approach to the scientific subject of their art work – by visiting scientists in their labs without prior research and using the conversation and interactions that result as the starting point for shared enquiry. Known usually for their explorations into how we experience the material nature of our world through science and technology – such as landscape formation through the tools of analogue modeling or how science translates nature on an atomic scale – they make predominantly image and screen based works where the data is presented in as raw a form as possible, without removing the extraneous information that scientists often tidy away to bring focus to particular findings. Working with the University of Strathclyde Quantum optical and computational group, Semiconductor have created immersive CG animations – using the same visual language and methods as the scientists – of the dynamics of the quantum realm.






## QuProCS

Quantum simulators are controllable quantum systems emulating the behaviour of other quantum systems whose properties are not easily accessible. Several designs of quantum simulators are currently being built in many laboratories worldwide, showing already some promising results.

However, the development of efficient probing techniques is still lagging behind, despite their crucial role. As a matter of fact, in most of quantum simulators measurement techniques are invasive and destructive. Not only do they destroy the very quantum properties from which the simulator stems, but also the quantum system itself.

QuProCS aims at developing a radically new approach to probing complex quantum systems for quantum simulations. The key idea lies in quantifying and optimising the of amount information that can be extracted by a single quantum probe, embedded in such a complex environment, as opposed to a classical one.

This project splits in two teams pertaining to two different aspects, complementary to each other.

One team is focused on developing the theory and carrying out experiments on quantum probes in ultra-cold atoms, for detection and characterisation of quantum correlations, quantum phase transitions, transport properties, and non-equilibrium phenomena.

The other team, also consisting of both theoreticians and experimentalists, is focused on how changing the properties of the environment via reservoir engineering modifies the behaviour of the quantum probe. The experimental platform is in this case quantum optical.

# Parting the waves

Parting the Waves takes the visual language and method of quantum simulations, as a framework for exploring how science describes and attempts to harness the quantum realm.

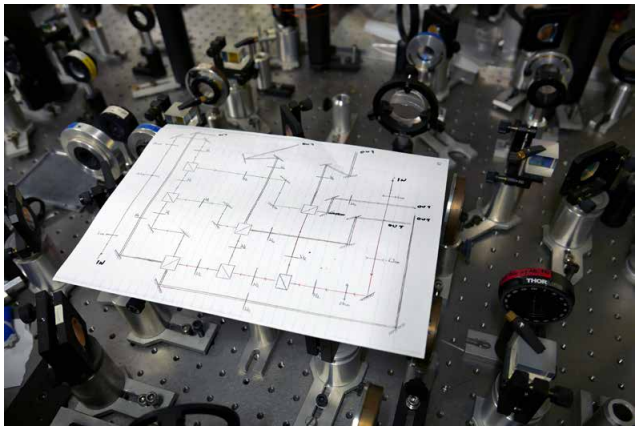
Semiconductor have taken as a starting point simulated 'surface plots': realised as three co-ordinate graphs, they present mathematical computations of particle interactions, in a quantum system. The plots appear as varying degrees of undulating waveforms, created by the intensity of particles interactions being affected by distance, over time. A pair of square screens installed at 90 degrees expands upon two moving image projections, becoming a graph-like object in the space, mimicking the system employed by scientists to present the simulations.

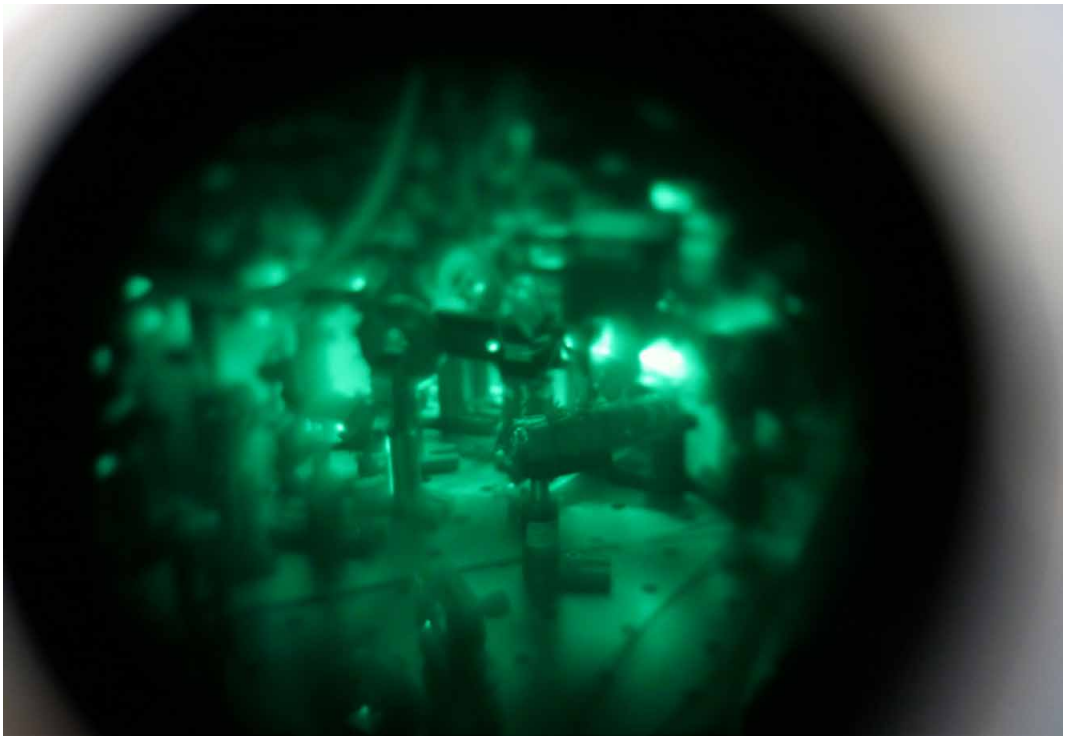
Sound drives the CGI work, generating and animating visual waveforms. Starting with Hertz: the standard unit for measuring frequency in cycles per second, specific tones have been selected which create harmonies and dissonances, to play with notions of phasing, shifting and interactions in a quantum system. As the tones shift, disturbing the system, so it responds visually, producing varying degrees of amplitude, wavelength and frequency which result in complex interference patterns. The colours are representative of the coding system scientists use, to identify specific parameters or patterns when model making.

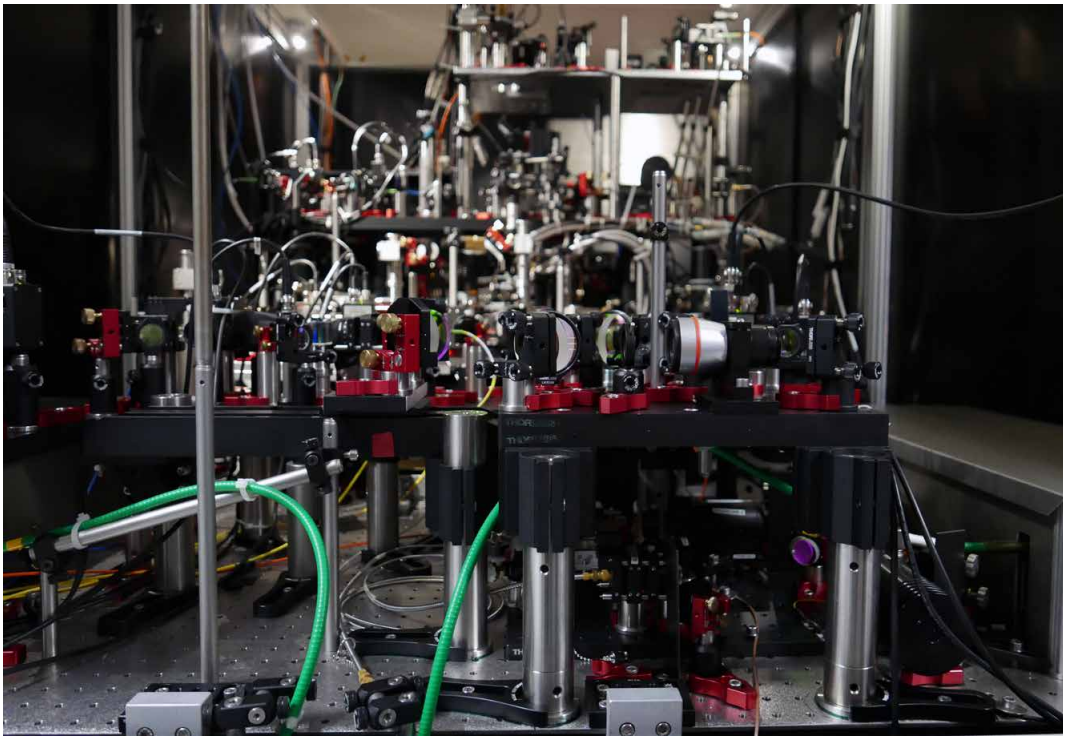
Visual and audible noise is used to introduce the concept of coherence and de-coherence in a quantum system: the point at which a systems behaviour changes from that which can be explained by quantum mechanics to classical mechanics. Other details hint at mathematical tools and terms associated with the phenomena of quantum systems such as; superposition, entanglement and wave functions.

Quantum simulations are approximations of nature that are modelled and then compared to other models, to gradually build up a picture of the phenomena being studied. The layers of modelling are a language by which scientists can communicate their findings and get closer to nature. Semiconductor are interested in the extent to which these tools and scientific products bear man's signature. By making a work where you experience nature through the language that is made to study it, they want to question how our experiences of nature are mediated through science.

http://semiconductorfilms.com/art/parting-the-waves/
2017
15:00
two channel HD moving image / three channel sound
A Semiconductor work by Ruth Jarman and Joe Gerhardt.







# The mystery of quantum computers

*Sabrina Maniscalco, coordinator of the QuProCS project — A step forward towards solving ultimate questions.*

Our computers, even the fastest ones, seem today unable to withstand the needs of the enormous quantity of data we have to deal with in our technological society. That's why scientists are working on computers using quantum physics, or quantum computers, so much faster and powerful than conventional computers.

What then is a quantum computer? An ordinary computer works with bits, where a bit has a single binary value, either 0 or 1. A quantum bit, or qubit, instead can store a zero, a one, both zero and one, or an infinite number of values in between. That increases enormously the capacities of calculations. We are still at the beginning of this new era of computing, hence there are for sure many ways to use this new technology that have yet to be discovered. For example, the factorisation of very big prime numbers, a task which is closely related to cryptography and security of passwords, could be one of the many possible uses of quantum computers.

According to Professor Sabrina Maniscalco, who heads the Turku Quantum Technology group in Finland, "The most famous quantum algorithm is Shor's algorithm. This algorithm, if running on a quantum computer, factorises integer numbers into prime factors faster than any known classical algorithm. This is remarkable as the slowness of prime factorisation is the basis of currently used methods to decipher messages."

But there are many other possible uses of this new technology. According to recent research reported in the peer-reviewed journal Science Advances, "The availability of a universal quantum computer may have a fundamental impact on a vast number of research fields and on society as a whole. An increasingly large scientific and industrial community is working toward the realization of such a device." Computing giants Google and Microsoft are investing a lot of money in this research field. By using quantum physics in computers, scientists could also in the future simulate chemical reactions, in order to facilitate drug design and improve machine learning.

Scientists are even imagining quantum computers not working alone; they are looking into the possibility of actual quantum bits being transmitted between individual quantum computing modules with connections created by electric fields. The aim would be to obtain a modular large-scale machine with an impressive computational capacity.

Professor Sabrina Maniscalco joined the QuProCS project, under the European Union programme Future Emerging Technologies (FET). The project develops a new radical approach to probe complex quantum systems for quantum simulations.

"A quantum computer would be mainly used for the same tasks as we currently use computers for. It would just be much faster. For that reason, we could solve computational problems that we cannot with any traditional computer," says Maniscalco, "But a full size quantum computer that could be used for various purposes is still under development. It may become reality sooner than we dared to expect!"

Finally, through quantum computing, scientists dream of investigating answers to ultimate questions such as the birth of life or the origin of the universe.

*By Rebecca Parsons*

# When sound drives a piece of art

*British artists are shaping the sound waves produced during quantum system simulations, so that the general public may grasp sophisticated mathematical concepts.*

Creating a piece of art inspired by a scientific discovery. That is a challenge embraced by Ruth Jarman and Joe Gerhardt, a UK artist duo called Semiconductor, who spent a period of time in Finland to collaborate with the Turku Quantum Technology group led by Professor Sabrina Maniscalco. Their hope is to make science more "visible" to a lay audience.

"The collaboration with Ruth and Joe has been great fun and very inspiring," says Maniscalco, "I'm very interested in the process of communication between people with very different backgrounds, in particular scientists and artists. The attempt to communicate sophisticated mathematical concepts to non-experts always forces us to find useful analogies, and pushes us to go to the core message of what a certain scientific concept is. This very often leads to a better understanding of our scientific research and forces us to take original viewpoints that stimulate creative insight."

During their six-month stay in Finland the artistic duo graphically represented the sound waves produced by the instruments during quantum system simulations. The artists think it is the sound which drives each piece of art. Without sound, there is no image.

The frequency of the sound waves creates harmonies and dissonances. Sometimes it produces large undulating waves, other times small waves, thus creating complex interference patterns. The works of art are also aimed at graphically representing the concepts of coherence and decoherence: "Coherence is when a quantum system exists and decoherence is when you lose a quantum system", says Ruth Jarman.

The artists consider their work as technological sublime. According to this theory, which adapts the concept of sublime expressed in Kant's Critique of Judgement to modern society, the aesthetic concept exalting the beauty is applied to technology that discloses a whole new range of sublime experiences. The creative duo learnt a lot about quantum science during their Finnish residency, run under the project FEAT, supported by the EU Framework Programme Future and Emerging Technologies (FET). "Professor Sabrina Maniscalco is infectiously enthusiastic about her science," say Ruth Jarman and Joe Gerhardt, "This spreads throughout the labs she works with and has meant we have had really dynamic experiences when visiting the laboratories and the scientists who work there."

Even complicated mathematical concepts can be a source of inspiration and creativity. After all science and art can overlap, since both are means of investigation.

*By Rebecca Parsons*

# Science: The language of the unknown

*The fascination of the unknown for producing artworks.*

"We are interested in the unknown, and as soon as you start looking at things you don't know about, you find that science is the language of the unknown, it's the frontier". This is how Ruth Jarman and Joe Gerhardt, a UK artist duo called Semiconductor, describe the essence of their work. They produce artworks which explore nature through the lens of science and technology.

It is generally believed that science is a cold and analytical matter. Nevertheless many artists throughout the history have been inspired by it.

"We've been working together for twenty years exploring the material nature of our physical world and how we experience it," says Jarman, "Over the years we have become much more interested in how science mediates nature, looking at the tools and processes of science and questioning where science ends and nature begins."

An example is Black Rain, a moving image medium which uses satellite image data to observe the space between the Sun and the Earth. Another Semiconductor work that creates visual interpretations of unknown worlds is Brilliant noise, which deals with solar astronomy. The artists have brought together some of the sun's unseen moments. These images have been kept in their most raw form, revealing the energy particles and solar wind as a rain of white noise.

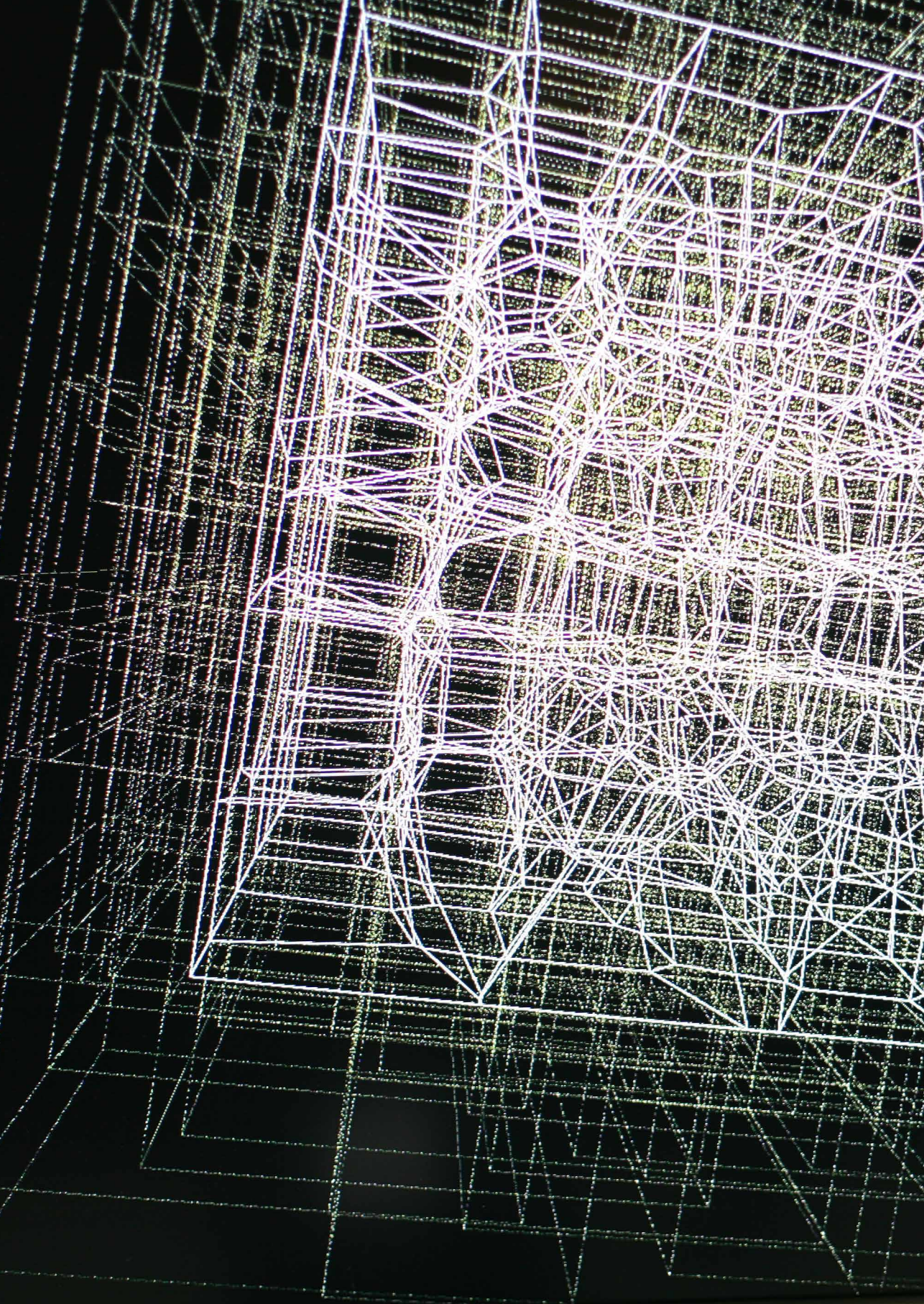
Ruth Jarman and Joe Gerhardt believe that sometimes art can help scientists to better communicate their difficult matter, finding new ways of exploring, representing and discussing science. That's the reason why the two artists have observed the quantum computing activity by scientists of the Turku Quantum Technology group. They spent six months in Finland with them, and graphically represented the sound waves produced by the instruments during quantum system simulations. The work has been carried under the project FEAT, supported by the EU 7th Framework Programme Future and Emerging Technologies (FET).

"Quite often science is complicated," Semiconductor says about this experience, "But art can provide a gateway for engaging people in scientific research and ideas."

6

# Pinar Yoldas & DIACAT

FEAT

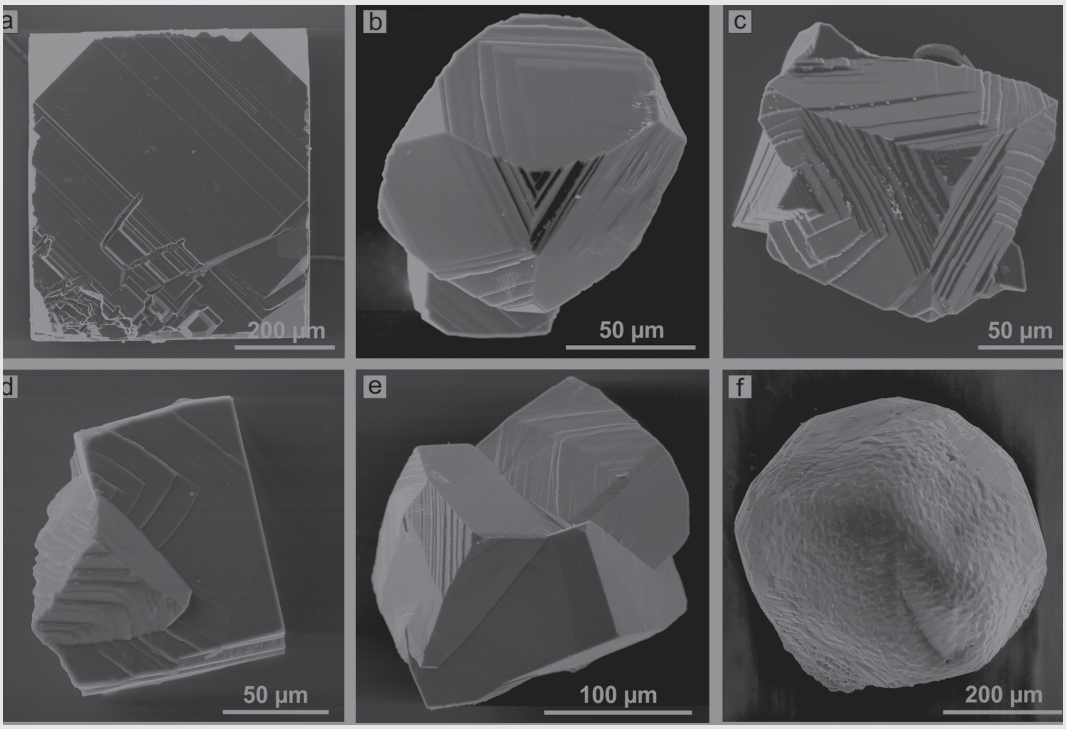


## Pinar Yoldas

Pinar Yoldas is an infradisciplinary designer/artist/researcher currently based in Ann Arbor, Michigan. Her work develops within biological sciences and digital technologies through architectural installations, kinetic sculpture, sound, video and drawing with a focus on post-humanism, eco-nihilism, anthropocene and feminist technoscience. Her solo shows include The Warm, the Cool and the Cat at Roda Sten Konsthall (2016), Polyteknikum Museum Moscow (2015),An Ecosystem of Excess, Ernst Schering Project Space among many. Her group shows include ThingWorld, NAMOC National Art Museum of Beijing (2014); Transmediale Festival, Berlin (2014), ExoEvolution at ZKM (2015),14th Istanbul Biennial (2015) ,Taiwan National Museum of Fine Arts(2016).

Pinar's residencies include the MacDowell Colony, UCross Foundation, VCCA, National Evolutionary Synthesis Center, Duke University, Quartier21 Künstlerstudio-Programm, Transmediale Villem Flusser research residency at UdK Berlin. She has been an invited speaker at SAIC, Haus der Kulturen der Welt, Northwestern University, Angewandte Kunst, University of Arizona, Reed College, University of Buffalo, BacNet15, Penn State and UCLA among many others. Her work has been featured in Arte TV, Die Welt, The Creators Project, Art21 Blog, Der Spiegel, Vogue Turkey and Artlink BioArt issue to name a few.

She holds a Ph.D. from Duke University where she was affiliated with Duke Institute of Brain Sciences and Media Arts and Sciences. She holds a Bachelors of Architecture from Middle East Technical University, a Master of Arts from Bilgi University, a Master of Science from Istanbul Technical University and a Master of Fine Arts from University of California, Los Angeles where she worked at the Art|Sci Center and the UCLA Game lab. Her book An Ecosystem of Excess was published by ArgoBooks in 2014. Pinar is a 2015 John Simon Guggenheim Fellow in the Fine Arts and a 2016 FEAT Future Emerging Arts and Technologies Award recipient.
She holds a bronze medal in organic chemistry in the national science olympics and had her first solo painting exhibition when she was five.




## DIACAT

DIACAT is a FET open research project funded by the European Union's Horizon 2020 Framework Programme for Research and Innovation.

The project aims to develop a completely new technology for the direct photocatalytic conversion of CO2 into fine chemicals and fuels using visible light.

The approach utilises the unique characteristics of man-made diamond, now widely available at low economic cost, to generate solvated electrons upon light irradiation in solutions (e.g. in water and ionic liquids).

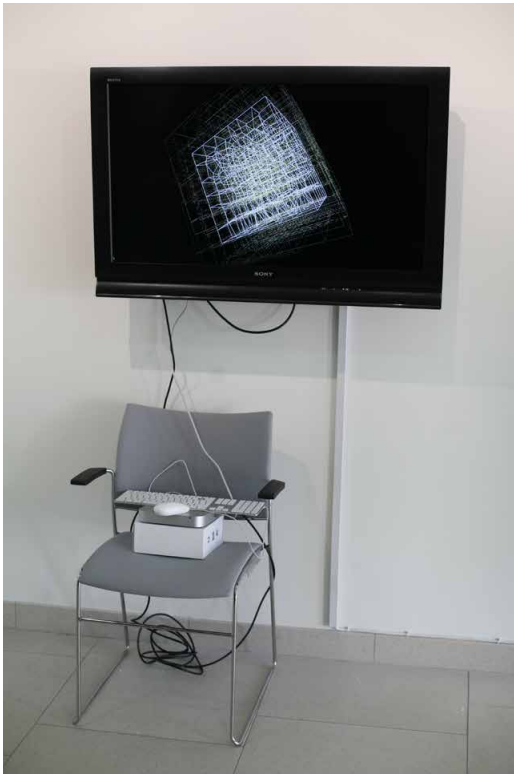
# Lattice Disruption

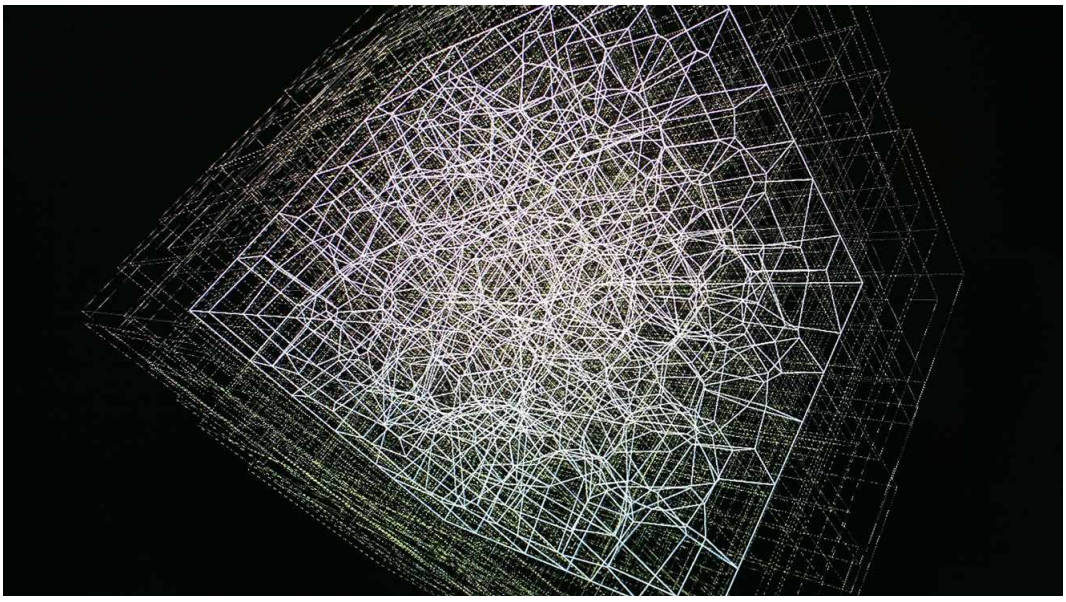
This piece is inspired by Dr. Anke Krueger's introductory papers on making artificial diamonds and their potential applications. Dr Krueger has researched the structural and chemical properties of this material, a key question in the DIACAT project which seeks to develop new technologies for the conversion of carbon dioxide into chemicals, and fuel, using visible light.

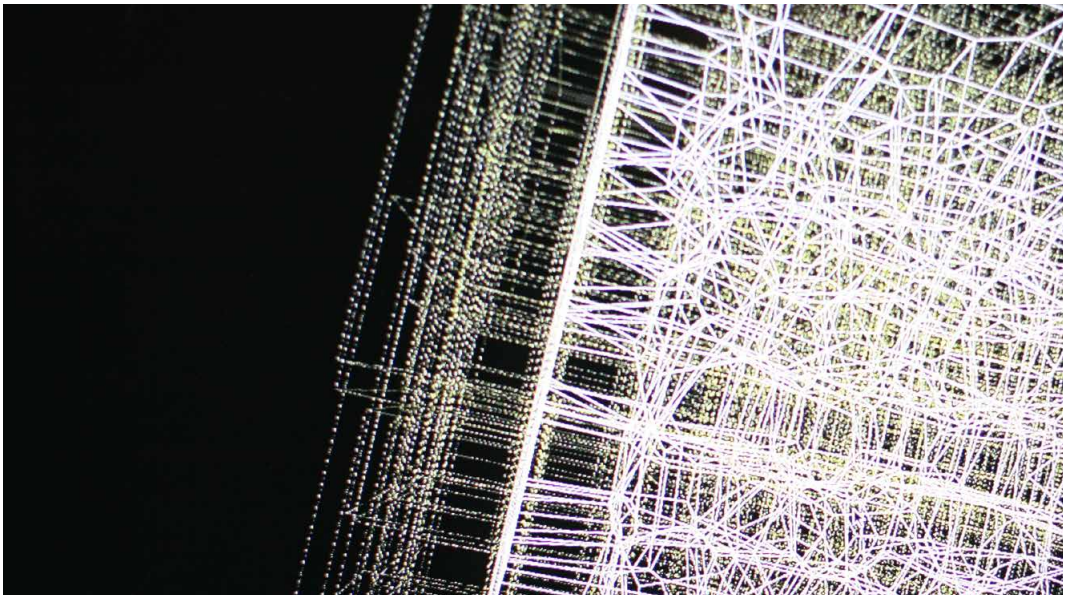
Diamond has a very ordered lattice structure whose study is a subject of solid matter physics. In this generative software work, the lattice is warped, applying a voronoi distortion. For the artist, the piece is a visual metaphor for the use of diamond's physical properties to transfer electrons, which in return causes CO2 to break down.

A recording of the artist talking about the FEAT collaboration can be heard at https://olats.org/feat/feat.php

Acknowledgements: Dr Anke Krueger







7

# Kerstin Ergenzinger & nuClock

FEAT

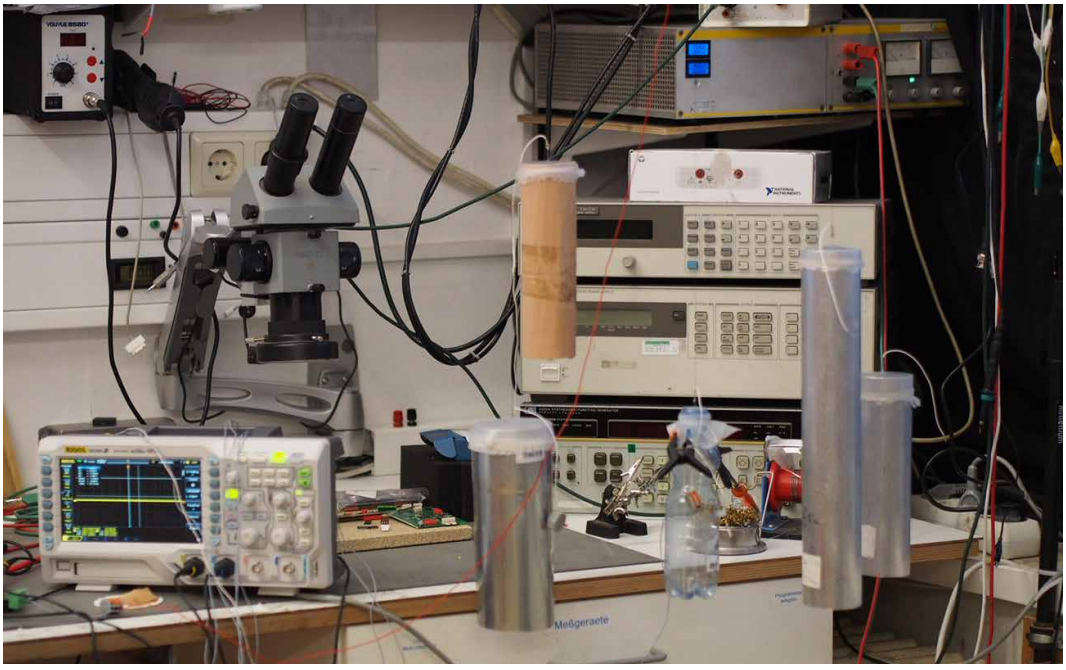
## Kerstin Ergenzinger / nuClock

After we met as affiliates of the FEAT initiative, the researchers from nuClock and myself, quickly decided to collaborate throughout the whole left four years of their FET project. This gives us more time to create an actually, dialogic exchange. Throughout this process, in the long run, we are looking for ways to develop something (process, situation, spatial structure), an experiment or art work, that opens up an area where - on first sight - abstract concepts and counterintuitive and elusive objects of observation enter the macro world of our human perception and reveal its entanglement with us and our close surroundings.

We started visiting each other in the labs respectively in my studio. So far, I visited the experiments and groups at the TU Vienna, at LMU Munich and at PTB Berlin, additionally Simon Stellmer from TU Vienna spent two days in my studio in Berlin. After showing each other the basis of our practices in its different working surroundings and experiments, some in action, we are now regularly following up via email and skype, namely with Simon Stellmer and Thorsten Schumm.

As the first practical approach, I am working on „a study on noise and precision", both phenomena we are engaged in from different point of views: The researchers from nuClock are developing experiments and strategies to observe and describe the fine transition from an isotope of the element thorium (thorium-229) to its excited isomer state, in order to - in the long term - use its energy difference = frequency to define the second with a even higher resolution than done today via the difference between two quantum states of an electron. This would lead to a time-signal-texture 100-times higher in resolution which would subsequently be implemented in technologies that fundamentally structure and inform our societies and our daily lives. In this high-precision filtering processes the researchers are predominantly confronted with detected noise.

Noise here is mainly an obstacle to overcome. Yet it is information incognito. This is one of the points where our interests and practices cross, literally technically, phenomenological and philosophical.



conceptual sketch:

a) digital system input: oscillating, shifting noise (white …)

b) analog, physically distributed and filtered in time and space:

c1) "noise" pulses are statistically/randomly distributed throughout
the field of Nitinoldrums -> percussive, rain like noise/sound patterns

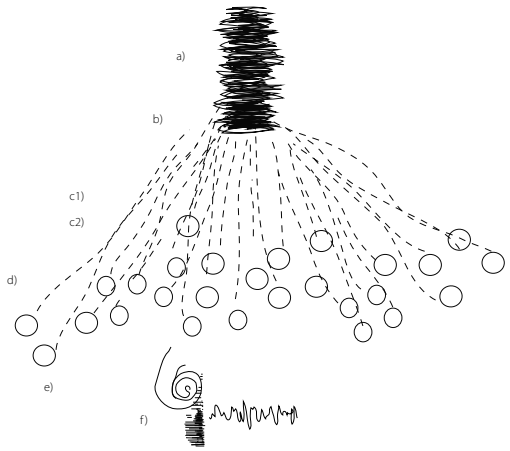
c1) the differing tubes/bodies of the drums filter
the equal intensities of the different frequencies of the "noise" pulses
by amplifying their own resonance frequencies -> "standing tones: harmonics and drones

d) the different types of Nitinoldrums are organized in groups/fields:
-> results in further spacial filter, potentially generating shifting acoustic signal patterns

e) delay and „unschärfe" due to materiality, the heating, cooling and tuning

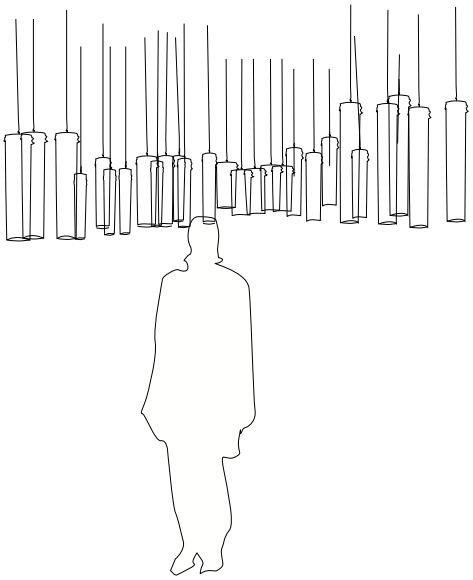
f) continuously decoding within our (plastic) brains and minds,
an ongoing detection process deploying neurological inscribed analogies.

conceptual sketch:




installation layout sketch:

installation sketch:

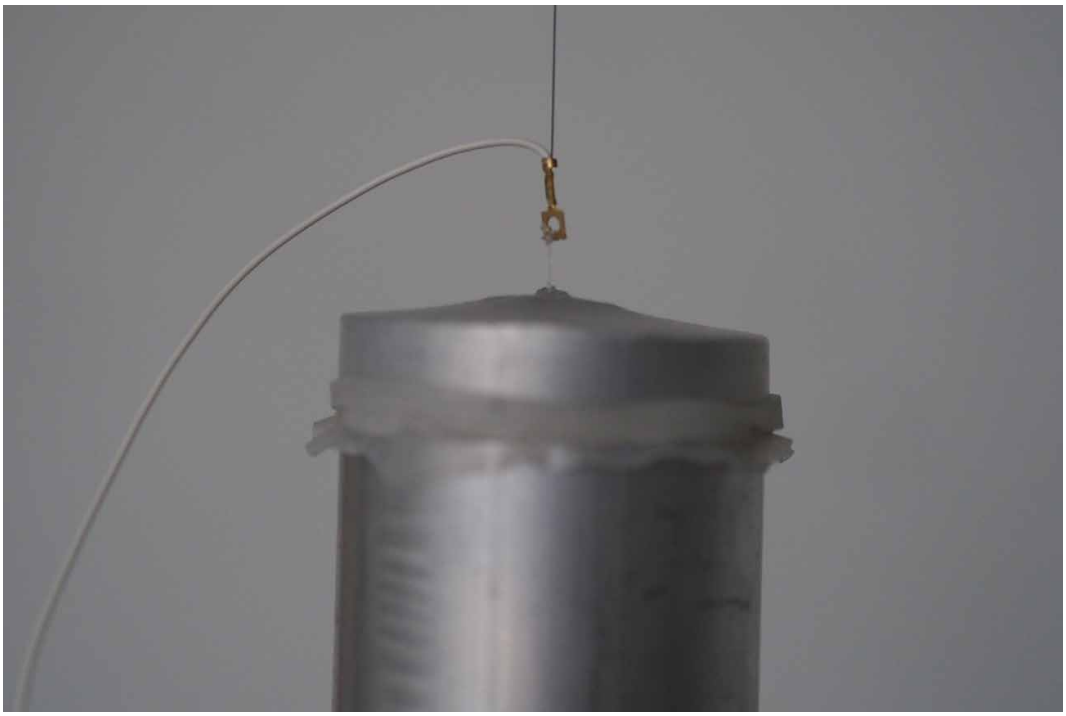


One of the basic interest in my work is the investigation of noise in a way that leads to alternative modes of orientation within our increasingly complex, technologized world. Noise is the condition for the constitution of meaning. However, without demarcations, noise is only noise. Therefore, I address the need for means of orientation; the need to draw distinctions within our unpredictable, eventful reality. In other words: the need to draw distinctions within the noise that surrounds us. I do not consider noise to be dissonant or semantic-free, but rather as raw data, in which awaits a tremendous potentiality. Thus, noise is not an inextricable residual that falls out of the symbolic order but rather calls for new methods and approaches to process this dynamic yet unpredictable raw material.

The before mentioned ‘study on noise and precision’ is a work in process that will consist of a network of acoustic instruments: custom-made string drums for which I use the robotic nitinol wire with its kinetic and sonic qualities as instrumental wire. In this piece, I decided to address our acoustic sense (the ear and its neurological correlative) because it has a significant higher resolution in time as our visual sense. A quality we mostly don´t consciously perceive, I think.

The noisy background behavior of quantum particles, that always leaves a rest of imprecision is often compared with falling rain. In the artwork, I take the natural noise of rain as a sensuous as well as a rich analogy we can perceive and relate to.

Right now, I am working both on refining the resonance tubes of the instruments and on the adequate ways to generate and transmit the digital input of shifting noise distributions. After this we plan to meet in my studio in Berlin to experiment with the instruments together. I aim to realize a system that is able to render noise, which is mostly understood as obstacle to be discarded, into a standing and at the same time fluctuating sonic momentum. A momentum, that interweaves percussive rain like noises and sounds with standing tones of amplified resonance frequencies and harmonics from the resonance tubes of the string drums. Here the challenge is to drag the visitors into an atmosphere which is noisy and precise at the same time. An atmosphere that amplifies the visitors’ perception and challenges them to become active listeners and observers.



# Nubis et Nuclei: A Study on Noise and Precision

Kerstin Ergenzinger (Berlin University of the Arts, 10587 Berlin, Germany); Thorsten Schumm and Simon Stellmer (Vienna University of Technology, 1020 Vienna, Austria)
E-mail: kerstin@nodegree.de.

*Submitted: <leave for Editor to date>*

**Abstract**

**This study sets out to explore the perception of noise, as well as the relation towards meaning or information that it might contain, in arts, science, and daily life. It is realized as an installation based on a suspended cloud of nitinol drums that create a sonic environment evolving in time and space. The instruments are driven by digital random noise. Roaming freely and listening, visitors become part of an ecology of noise. Exploring the differing regions in time and space, what appears to be noise can shift to a "meaningful" signal. This process of discovering a clear signal in a noisy background holds strong analogies to the scientific search for a nuclear resonance performed in the "nuClock" project.**

The motivation of the artwork is to explore and understand noise in a way that leads to alternative modes of orientation within our increasingly complex and technologized world. Noise is not considered to be dissonant or semantic-free, but rather as raw data, which treasures a tremendous potential [1]. Thus, noise is not an inextricable residual that falls out of the symbolic order, but rather calls for new methods and approaches to process this dynamic yet unpredictable raw material [2]. Besides the sonic realm the artwork questions the close connection between noise (in a mathematical sense) to measurability and precision [1].

The "nuClock" consortium, a team of researchers from nuclear and quantum physics, seeks to detect and characterize an elusive nuclear state in the unique isotope Th-229. This state forms the basis of a future *nuclear* clock that holds the potential to outperform today's atomic clocks. With a precision of up to 20 digits, it would be used for global navigation, synchronization of telecommunication networks, and basic research. The first step in its implementation is the detection of a very faint frequency masked by strong noise.

Our collaborative study on noise and precision is undertaken at the crossing of the technological and the metaphorical. Noise is where our practices cross, literal technically, phenomenologically and philosophically. Even in science, noise is mainly an obstacle to overcome by improving statistics. It is information incognito, the condition for the constitution of meaning.

"Nubis et Nuclei" is a sculptural sound installation. It consists of a number of custom-made acoustic instruments, nitinol drums. The digitally controlled instruments derive from string drums, using nitinol as instrumental wire [3]. They are arranged in a cloud-like formation and suspended from the ceiling [Fig. 1]. The field of instruments renders the digital input of noise into a standing momentum that appears to evolve in time. Percussive rain-like noises and sounds interlace with standing tones of picked and amplified resonance frequencies. Surrounded by an ecology of noise the visitor is addressed as a listening body and invited to follow the acoustic and tactile rhythms emitted by the cloud of instruments.

The acoustic sense, the ear and its neurological correlative, has a finer time resolution than the visual: our ear is the primary organ to measure rhythm and time. In contrast to vision, which captures only a fraction of our surroundings hearing covers the entire sphere around us. [4] Note that until the advent of digital communication, precise timing signals (*e.g.* church bells, reference frequencies) were all acoustic [5].

We now describe the technological implementation: White noise is digitally fed into the control system. The signals are randomly distributed over the field of nitinol drums. Each drum, consisting of a tube of variable length and material, has its own characteristic resonance frequencies: in this way, the drums act as a set of random band pass filters, giving rise to standing tones, harmonics, and drones. The drums are arranged such that local acoustic signal patterns appear: the atmosphere is noisy and precise at the same time. Based on the kinetic quality of the nitinol wire we will experiment with an analog feedback system, which allows the sonic environment to further modulate itself, as well as the visitor to alter her/his surroundings. By probing various locations within the cloud of noise, she/he is challenged to define "meaningfulness" of a potential signal, and to develop a search strategy. Eventually, this study is also an experiment and exercise in awareness and fine-tuning.

We thank Thomas Laepple for technical assistance and acknowledge financial support through the European Union's Horizon 2020 research and innovation programme under grant agreement No 664732 "nuClock". The project is co-funded by Einstein Foundation Berlin and realized with the support of the Graduate School at the Berlin University of the Arts.

Our work is affiliated to FEAT, an initiative of eutema GmbH (AT), Stichting Waag Society (NL), and youris.com (BE). It has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 686527 (H2020-FETOPEN-2015-CSA).

**References and Notes**

**1.** Nathanja van Dijk, Kerstin Ergenzinger, Sebastian Schwesinger, and Christian Kassung (Eds.), *Navigating Noise* (Cologne, Germany: Verlag der Buchhandlung Walther König, 2017).

**2.** E.g. amongst others artistic practices by Bruce Odland and Sam Auinger: Chris Salter, *Alien Agency, Experimental Encounters with the Art in the Making*, MIT Press 2015, pp. 21-84

**3.** Nitinol is a super-elastic shape memory alloy out of nickel and titanium that exhibits robotic and acoustic effects.

**4.** Marshall McLuhan and Bruce R. Powers, *The Global Village, Transformations in World Life and Media in the 21st Century* (Oxford University Press, 1993)

**5.** Peter Gallison, *Einstein's clocks, Poincarés maps. Empires of time* (New York City, USA, W.W. Norton & Co., 2003)

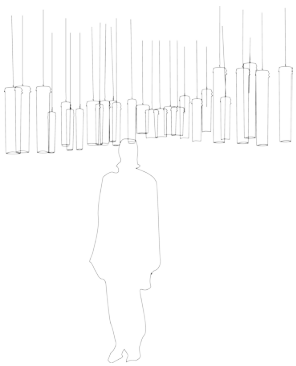


**Fig. 1. Sketch of the installation, showing an observer moving below cloud of nitinol drums. (© Kerstin Ergenzinger)**

# Various articles
# Workshop papers

# WHAT'S ART GOT TO DO WITH IT? REFLECTING ON BIOART AND ETHICS FROM THE EXPERIENCE OF THE *TRUST ME, I'M AN ARTIST* PROJECT

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Email: <anikburo@gmail.com>.


*Submitted: 19 February 2017*

**Abstract**

Bioart and biomedical art is a blossoming field with a whole new generation of artists, the DIYbio movement enabling more people to get involved, and discoveries in bioscience bringing in new challenges. Supported by the Creative Europe programme of the European Union, *Trust Me, I'm an Artist* is a project initiated by artist Anna Dumitriu and ethicist Bobbie Farsides to provide a platform for discussing bioart and ethics, for sharing knowledge and building capacity. This article reflects upon my journey through the different art projects and how foregrounding ethics challenged my usual art critic approach.

*Keywords:* Ethics, Bioscience, Biomedicine, BioArt

Among the reasons that brought me into the *Trust Me, I'm an Artist* project [1], one was to dig into the many and complex issues of ethics and bioart with the hope of better embracing all the questions raised by benefiting from the knowledge of the various people involved.

A second reason was that, in only a few years, from 2010 on to give a loose timeframe, I witnessed the development of a more cautious and restrictive approach and attitude to what could or could not be done or exhibited as art with biotechnologies. Simultaneously, the field blew up with a whole new generation of artists pushing the boundaries, the DIYbio movement enabling more people to get involved, and discoveries in bioscience and biomedicine bringing in new challenges.

*Trust Me, I'm an Artist* was initiated and led by artist Anna Dumitriu and ethicist Bobbie Farsides in 2011 [2]. It consisted of the organization of public events where an artist proposed a bioart work to an ethical committee composed, as much as possible, on the same basis of such a committee in a scientific context of the country where it takes place. Obviously, this set up includes *de facto* a performance/staged element. In 2015, with funding from the Creative Europe program of the European Union, the project developed and expanded under the lead organization of the Amsterdam-based Waag Society with a focus on art and biomedicine and an expressed goal to help build capacity and shared knowledge for artists, scientists and cultural players (Fig. 1) wanting to engage in those areas and types of collaborations.

In the first edition of *Trust Me, I'm an Artist,* I co-organized with Anna Dumitriu the hearing in Paris of Marion Laval-Jeantet and Benoît Mangin from Art Orienté Objet about *Que le panda vive en moi* [3], a project that could have followed their famous *Que le cheval vive en moi !* ("May The Horse Live in Me!"). In the second round, to which I am reflecting here, I attended the different projects as the director of Leonardo/Olats and in my capacity of art critic, producing a series of podcasts [4] with both the artists and the curators and writing a diary [5] throughout.

In this article, I would like to reflect upon and come back to some of the points that have been significant for me, either by providing a conceptual framework, by opening up new questions, or by highlighting unanswered issues that require further debate by society at large.

Practical ethics in biotech and biomedicine research laboratories as well as legislation form a blurry landscape with varied rules and regulation [6] that seem to be in constant flux, without a shared homogeneity among the EU countries. Here and there the weight of local history, sometimes tied to medical scandals, can be witnessed [7], not to mention the moral and mental scars left by the Second World War. But, more importantly, it is our conception and beliefs about Life and the Living that is currently shaken and has become unstable: that is the very issue of the redefinition of ethics as the ground basis to our attitude toward and relations to our fellow humans and other living creatures with whom we are sharing the planet; analyses sometimes resembling programmatic discourses and *vice versa*.

## What's art got to do with it?

Where does bioart stand in this landscape? Different positions can be stated, that are not mutually exclusive.

The first one is that bioart should comply with the current agreed ethics of the environment where it is created. This being particularly true when the creation is done in scientific facilities and in (official) collaboration with researchers. Here comes the first obstacle: in science, you are not allowed to experiment on yourself, which is at the basis of art from immemorial time up to current body art and performance. This question, 'can I be third party to myself,' was raised by Howard Boland with his *Cellular Propeller* project [8] in which he wanted to use his own sperm cells for a synthetic biology artwork. The second difficulty is that what is acceptable for research, especially in medicine, is not necessarily considered so for art. Ethical rules in research and medicine is a delicate balance between risks (for humans) or abuse of, pain or fatal damage to the creatures used (non human and human) in regard to the potential (usually health and well-being) benefits (for humans). Could "aesthetic interest" be considered a criterium for a "reasonable risk or damage-necessity"? We do judge art projects daily for grants and programs of all sorts and it seems to me no less or no more (ir)rational or subjective than the criteria used in science and medicine.

In contemporary western societies, being provocative and breaking boundaries is considered one of the roles of art. By asking to do for art what is allowed for science, by asking to do what is allowed in labs outside of the labs (security provided), by asking to do in labs what is (generally) allowed in art, bioart is breaking boundaries. By exhibiting our very contradictions—that under certain circumstances you are allowed to do what is otherwise considered immoral— art is not only questioning the ethics of (bio)science but contributing to the larger debate of redefining where we put the limits of what is acceptable or not and setting the new crossed hybrid hierarchies among the Living that we are collectively elaborating. Our consideration toward animals but also plants and even potential non carbon based "creatures" is shifting and is the site of strong debates [9]. This was at the heart of Špela Petri 's *Confronting Vegetal Otherness: Skotopoiesis* [10] and Ivor Diosi's *Molding the Signifier* [11]. By casting her shadow upon growing cress, Petri does not break any ethical rules but brings in our unconscious hierarchies and, after *zoe*, asks for a new perspective on *phyto*. On a more speculative side, Diosi is addressing the unanswered question of our attitude toward artificial intelligence, the ultimate Other.

## Power and Responsibility

Ultimately, ethics is a dual issue of power and responsibility. Disentangling the power of who upon whom and the responsibility of who toward whom as expressed in and by the art projects where several layers of responsibility and recipient are

intertwined has been for me one of the nurturing component of *Trust Me, I'm an Artist*. The responsibility is, of course, in the hands of the artist as the one at the initiative of the artwork but it is shared with the curator, the producer, the scientist and their respective institutions. The first recipient toward whom this responsibility is targeted is naturally the "Other," the "subject-object," the living creature which is used or part of which is used for the work. It is interesting to see the increase in concern about the use of human body parts or waste that is reaching nowadays the cells themselves. If there are some grounds for this due to some misuses on the one hand and to the evolution in bio-research that could allow for a potential control or abuse on the person on the other, it expresses a deeper crisis. This reveals the tension regarding what defines identity, the ambivalent fear (attraction-repulsion) of the commodification of the human body and the disintegration of the idea of ownership of oneself not to mention belief systems and deep archaic engrams. Gina Czarnecki is confronting those issues and beliefs, the hopes and threats of personalized medicine in *Heirloom*. In this piece, she creates a "living portrait" of her young teenage daughters by growing their skin cells onto glass casts. High resolution 3D scans of the girls' heads (3D printed) that capture their face structure have been produced and are exhibited next to the incubator in the gallery. This work has been one of the most challenging for me. Building upon one of the most ancient form of art, namely the portrait, and pushing it aesthetically further, not only does it embody the complex mesh of biotechmedical components (positive and negative) together with our conflicting fantasies and dreams but it also reveals, symbolically, the structure of power: the everyday banal power of parents over their children and the more intricate medical power. It is Gina Czarnecki who signed the consent form for the research laboratory to sample her children cells that would become the material for her own artwork. Even based (or because based) on a symbolic level, this was for me, a critical knot of ethics.

Less discussed when dealing about ethics, the artist and the audience are other recipients toward whom responsibility is exercised. This came up with Martin O'Brien durational performance *Taste of Flesh / Bite Me I'm Yours* [12]. Can we let an artist take risks that bring him/her "beyond the red line"? Tricky question indeed. Who is "we"? Only the curator and the producer-organizer? Or can the audience have a say during the performance? But who would dare to interrupt a performance that is explicitly "at the edge"? Isn't the artist responsible for him/herself? Where is the line drawn? As long as it is "made public," isn't an artwork considered "safe" both for the performer and his/her audience?

There is an acceptance that sport can kill the players and a sort of tolerance that it can also kill the audience. The "Paris-Dakar" rally has never been stopped when people were killed or injured along the road, nor has the "Tour de France". No one would talk about ethics in these cases but about regulation and safety to minimize the risks. By, unconsciously, placing art in the representational or metaphorical realm, in the "humanities side of life," we think that it is, and must remains, harmless. But art can be (is?) also "for real" and therefore may include risks. In 1993, in *Delusions of Self-Immolation* [13], Erik Hobijn was setting fire to voluntary spectators protected by a thin fireproof gel before extinguishing the flames. The people would sign a release form. The same procedure has been used by many other artists. No one refers to ethics in those cases, only about safety and legal regulations. Why is it becoming ethics when applied to bioart? Could those release forms be considered the equivalent of the medical consent forms that I have always seen as a legal way to cover the doctors and health institutions rather than truly being a protection for the patients?

*Trust Me, I'm an Artist* put on the table the delicate and intricate boundaries between what is legal, moral and ethical. Approaching art from an ethical perspective first has been both interesting and a critical point for me. As an art critic, I deal with aesthetic first. Obviously, during the course of the project, I tended to approach the bioart works that I was encountering, within and outside of the project, with "ethical lenses" at the forefront. But the interest and power of an artwork, very much like in science, is where its aesthetical strength confronts its ethical challenges. Reaching the end of the project, my temporary conclusion would be that ethics might be a collective agreement about how immoral we allow ourselves to be.

**Fig. 1. *Trust Me, I'm An Artist* workshop at the Medical Museion in Copenhagen (© Annick Bureaud)**

**References and Notes**


**1.** *Trust Me, I'm an Artist: Developing Ethical Frameworks for Artists, Cultural Institutions and Audiences Engaged in the Challenges of Creating and Experiencing New Art Forms in Biotechnology and Biomedicine in Europe* is supported by funding from Creative Europe and is a collaboration between Waag Society, Brighton and Sussex Medical School, Arts Catalyst, CIANT, Kapelica Gallery, Medical Museion, Capsula and Leonardo/Olats. The lead artist on the project is Anna Dumitriu, and the lead ethicist is Professor Bobbie Farsides. More about the project can be found at <http://trustmeimanartist.eu/>.

**2.** <http://artscienceethics.tumblr.com/>.

**3.** <http://artscienceethics.tumblr.com/DuChevalAuPanda>.

**4.** <http://olats.org/trustme/podcasts.php>.

**5.** <http://olats.org/trustme/journal.php>.

**6.** Anna Dumitriu, "*Trust Me, I'm An Artist:* Building Opportunities for Art & Science Collaboration through an Understanding of Ethics," in *Leonardo* **51**, no. 1, 2018 (forthcoming).

**7.** Gina Czarnecki and John Hunt, *"Heirloom:* Living Portrait of and for the Artist's Daughters Created Out of Their Own Cultured Cell," in *Leonardo* **50**, no. 1, 2017

**8.** <http://trustmeimanartist.eu/projects/cellular-propeller-howard-boland-project/>.

**9.** Carried by theoreticians and philosophers such as Donna Haraway, Rosi Braidotti, Michael Marder, Monika Bakke (in English) and Dominique Lestel, Vinciane Despret (in French).

**10.** Spela Petri , "The Conundrum of Plant Life," in *Leonardo* **49**, no. 3, 2016.

**11.** Ivor Diosi, "*Molding the Signifier:* Codesculpting the Possible Shapes of a Future Consciousness," in *Leonardo* **50**, no. 1, 2017.

**12.** Martin O'Brien, "Flesh-Eaters: Notes toward a Zombie Methodology," in *Leonardo* **49**, no. 3, 2016.

**13.** Erik Hobijn http://v2.nl/archive/works/delusions-of-self-immolation.

# Truth Emerging from Leading-Edge Art/Science/Technology Interaction

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**Abstract**

The FEAT initiative organized and studied residencies of leading international artists in European Future and Emerging Technology projects. During the residencies, the artists closely collaborated with engineers and scientists on fundamental research in visionary areas of novel technologies not solely as an artistic endeavor, but also to investigate effects of artistic engagement on technoscience. Effects of the collaboration are visible on many levels including fundamental questions about the technoscientific project objectives, ethical aspects, and the aesthetics of scientific experiments. Interactions also resulted in long-term relations and opportunities for scientists to engage with artists in a shared effort to uncover truth.

Future and Emerging Technologies (or FET) is a part of the European Commission's framework programme that focuses on fundamental research in high-risk, visionary technology fields. FET and in particular FET Open projects are expected to initiate radically new lines of technology through unexplored collaborations between advanced multidisciplinary science and cutting-edge engineering. While FET research often is of a fundamental nature, it is still technology development with a long-term application perspective. This makes FET a very interesting case to study. For example, the project *nuclock* studies the transitions from an isotope of the element thorium-229 to its excited isomer state to eventually use its energy difference to define the second with an extremely high resolution. This could result in novel clocks up to 100 times more precise than atomic clocks today. *DIACAT* develops a new technology for the direct photocatalytic conversion of CO2 into fine chemicals and fuels using visible light. *subCULTron* are developing a culture of robots designed to live in challenging, human polluted environments, where they will monitor their surroundings.

We designed the FEAT residencies in close collaboration with the Waag Society in Amsterdam. Our aim was to stimulate take-up of FET research results and create internationally significant new forms of impact and innovation by embedding and supporting high profile international artists with FET projects. Following an open call, independent evaluators chose artists from over 250 applications. We gave the artists the opportunity to choose from about eighteen FET research projects (Fig. 1). As a result, the residencies cover very diverse areas of research and technology such as robotics, synthetic biology, quantum physics, chemistry, and supercomputing. For about nine months, experienced artists developed artworks in close interaction with scientists from the different research labs.

Although the interaction of artists and scientists resulted in the creation of artworks, this was not its sole purpose. The project was an initiative to make technology project results visible with nonscientific audiences including innovators, research managers, and citizens and to stimulate innovation through transdisciplinary approaches and take-up of those results. Another objective was to study the impact of artistic collaboration on researchers, to expand the scientific discourse in an ethical dimension and better understand the impact of art/science collaboration for long-term technology development.

**Fig. 1. The FEAT collaboration teams at the Matchmaking Workshop in Amsterdam. (© Erich Prem. Photo: Franz Bergnuber.)**

## Art, Science, and Technology Collaboration

The methodology for FEAT is based on previously identified recommendations resulting from the ICT & Art Connect initiative [1]. It goes beyond these approaches by emphasizing embedding of artists in a longer-term interaction from the early research phases by awarding residencies and performing case-by-case mentoring, but building on openness and hands-on direct collaboration. Therefore, identification, selection, and coupling of the artist and the FET project was based upon affinity and interests of the artists in the specific FET area and a residency period of nine months was chosen. This aimed at a strong interaction between artists and scientists to facilitate an early development of trusted relationships. Such mutual trust is not always easy to develop, but important for a creative working environment and for very practical reasons including for example scientists granting the artists access to all data.

Hands-on collaboration means that artists were practically involved with their cooperating FET project and worked on the emerging technologies. This implies spatial proximity, but also topical exchange. Artists could acquire specific technical competencies, e.g. laboratory techniques. While some artists chose to work closely with their research partners and even develop their artwork in collaboration with the scientists, others preferred visiting the laboratories for a set period and then returned to their studio to develop the artwork on their own. We expected that such openness about the format of the residences would lead to high-quality results given the experienced background of the artists. We would perhaps choose a different set-up in the case of artists less experienced with scientific collaboration.

## FEAT within the Science Discourse

Nowadays there is an increasing number of science and technology programmes that invest in artists, e.g. the European Commission's STARTS initiative in the Framework Programme for Research "Horizon 2020". The explicit rationale as described in call texts is to increase the impact of scientific work, foster new ways of thinking, and stimulate innovation emerging from art/science cooperation, cf. [2]. To the best of our knowledge, FEAT is the first initiative to pair artists with research projects that have long-term engineering as well as basic research objectives. The FET projects are special as they aim at traditional scientific truths, usually in the form of predictive models of reality. At the same time, they seek to realize purposeful technical function and technical principles based on such models. It is not at all clear how the arts fit in with research that is at the same time scientifically oriented and technologically minded. It is particularly unclear how an

artistic stance—without considering any design aspects or decorative ambitions—contributes to such technoscientific processes. FEAT was conceived with the explicit aim to study the effects of artistic residencies on technoscience and on research management. Practically, we closely monitored the residencies, organised workshops to discuss experiences, and performed interviews with artists and scientists about their experiences.

## Outcomes and Findings

The works that emerged from FEAT presented in this issue show outcomes and impacts from the art/science and technology interactions on many levels. As expected, the artists ask fundamental questions about science and technology, e.g. about the project objectives which they often critically examined. As (relative) outsiders to the world of science, artists are in an excellent position to devote time and energy to societal context which may be well known to the scientist, but to which the researchers can devote little time in their daily work. Scientists reported how the interaction with artists liberated them from their daily lab routine, permitted a fresh look at their own work, and allowed to devote explicit time for less goal-focused deliberation.

The artists also provide us with a more direct access to the aesthetic qualities of experiments than scientists who require an elaborate theoretical scaffolding of their work for their work.

FEAT's long-term residencies mostly led to longer-lasting interactions that go much beyond just the single residency and are indicated by mutual follow-up invitations to collaborate and a shift in the personal networks of the researchers (and obviously, the artists). Scientists and engineers do not remain mere suppliers of "inspiring environments" as longer-term residencies make it possible for the artists to acquire competencies in scientific and engineering techniques which they later use in creating works of art. Also, the artists are often fascinated by new materials and become early users of emerging technologies in ways that were not predicted by those first developing the technologies. It must be noted that the impact assessment of science and technology programmes requires years and often decades and the full effects of FEAT are therefore not fully visible yet.

## Discussion

The art/science programmes funded by the EC clearly argue that art has a *function* to fulfil in science and technology, in fact they refer to a range of functions from science communication to enhanced creativity, and even innovation. For me, the artworks presented in this issue concern the aesthetics of scientific experiments (Evelina Domnitch and Dmitry Gelfand); they point out the emotional aspects of technology (Anna Dumitriu); and concern ethical aspects (Spela Petric & Miha Tursic). They do not just serve technoscientific work, they affect the very subject matter of the research and engineering endeavour.

The artists in FEAT created artworks that aim to unveil key aspects of technoscientific work. For example, they focus on the immediate aesthetics of an experiment; they provide more linguistically mediated narrative and reference to the history of technology and its ethical consequences; or they simply question the purpose of technoscientific endeavours to compute meaning from data. These efforts are very much aligned with recent proposals from philosophers of technology. Peter-Paul Verbeek discusses the need to find new ways of understanding how technologies affect human subjectivity and how humans can develop responsible relations to their technologies [3]. Similarly, Sabine Roeser has suggested to include emotional aspects in the work of engineers to improve ethical insight [4]. To both proposals, the involvement of artists in technoscience may be a very practical answer.

I believe that one way of interpreting the FEAT residencies is as an effort of (re-)connecting three different strands in one activity: (i) a basic science activity that aims to understand the world by means of a model of reality; (ii) a technological activity related to this model, using it for human purposes; and (iii) an artistic process of creation bringing forth truth in works of art. This latter aspect refers to Martin Heidegger's nature of "things" and artworks [5,6], i.e. objects brought about in human acts of creation. Heidegger uses examples of tools and works of art as results of related, but different creative acts. While tools emerge from practical interest with a clear purpose, works of art may be said to carry the reason for their creation in them. While tools as artefacts point to purposes outside of them, works of art have no such clearly identifiable purpose nor are they clearly pointing to something else except for truth [7]. A logical connection between science, art, and technology then can be made as different ways of purposeful creation of valid expressions.

The FEAT residencies of artists with leading-edge technoscientific research projects created three different, but intimately related creative processes that may at times support or disturb each other. These processes are unpredictable as too many details depend on the precise setting, on the individual people involved, but also on organisational settings, time-plans and even organisation boundaries. They resulted in more than just aesthetic commentaries on the scientists' way of world-making. They went beyond an ethical exercise questioning the engineer's intentions, or a meta-philosophical one that tries to undo the potential harm arising from a reductionist technoscientific endeavour. All this may be at work in FEAT projects, but the residencies are not focused on such now traditional dichotomies. They facilitate co-creative processes which are surprisingly united in the intention to uncover truth; not just any or one, but truths shared between science and art. If we are lucky, this creation may even go beyond the schismatic perspectives of science as the domain of eternal but useless truth on the one hand or purpose-driven but purely instrumental and post-industrial business on the other. Artists then would be tasked with a new function that many may not even realize as necessary today: to re-unite science and technology.

**References and Notes**

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**1.** Camille Baker**,** "ICT& ART Connect: Connecting ICT and Art Communities Project Outcomes" in D. England et al. (eds.), *Curating the Digital,* (Springer Series on Cultural Computing) DOI 10.1007/978-3-319-28722-5_7

**2.** Erich Prem, *Innovation Opportunities Emerging from Leading-Edge Art/Science/Technology Interaction*, Proceedings International Society of Professional Innovation Management (ISPIM, 2017).

**3.** Peter-Paul Verbeek "Accompanying Technology" in *Techné*, 14:1, Winter 2012.

**4.** Sabine Roeser**,** "Emotional Engineers: Toward Morally Repsonsible Design" in *Science and Engineering Ethics* (Springer, 2012) 18:103–115.

**5.** Andreas Luckner, "Ding und Bestand," in A. Nordmann, A. Kaminski, C. Hubig, G. Grimm, P. Gehring (eds), *Jahrbuch Technikphilosophie 2015, Ding und System* (Zurich, CH: Diaphanes, 2015).

**6.** Martin Heidegger, "Das Ding," In F.-W.v.Herrmann (ed.), *Vorträge und Aufsätze* (Stuttgart, DE: Klett-Cotta, 2004).

**7.** Martin Heidegger, *Der Ursprung des Kunstwerks*. (Itzingen, DE: Reclam, 1986).

# Workshop Result Paper 1

*Knowledge in Art, Science and Technology*
*FEAT Vienna Workshop - JUNE 27th & 28th 2016*

## About FEAT

The aim of FEAT is to stimulate take-up of FET research results and create internationally significant new forms of impact and innovation by embedding and supporting high profile international artists to develop innovative artworks through deep engagements with FET projects. The project will embed six artists within FET projects where they will collaborate to develop and create new artworks that will be showcased internationally through exhibitions, participatory workshops, debates and media campaigns, concluding with a significant final exhibition and symposium.

The project will enable FET researchers to work collaboratively with leading artists to develop new artworks that critically work with and reflect on FET project research and results to enable radically new technologies to reach the widest possible audiences through international exhibitions, the global media and socially engaged participatory events including festivals, debates, workshops and discussion events. FEAT will demonstrate how novel perspectives on ways that FET results can be used for social innovation and global development will arise through the process of collaboration and dissemination of the work. We will give confidence to FET researchers to enable them to embrace creative interactions for innovation by providing new frameworks for successfully collaborating with artists to drive innovation in Europe.

Our measureable high-impact outputs will prompt new ways of thinking about ways in which FET results are shared by reaching out to non-traditional, diverse audiences and stakeholders in ways that are meaningful to them, through critical reflections, and both emotional and intellectual engagements. By catching the imagination of the public and the media by providing tangible contexts for radically new technologies within our future cultural life and enabling a space for societal debate we will significantly enhance take-up of FET research results.

## Introduction - Ways of Worldmaking in Art, Science and Technology

*By Dr. Erich Prem*

In all of these three fields - art, science and technology - we are dealing with constructions. When artists produce works of art, when engineers produce works of engineering and when scientists produce theories, there is always a process of creation. What we must ask ourselves is: is this just by chance or is there an underlying principle? On his blackboard, Richard Feynman famously left the statement “what I cannot create, I do not understand” and there are similar quotes by Ludwig Wittgenstein (“we make to ourselves pictures of facts”) and Lucas Pawlik (“we only understand what we construct”). All of these quotes point at a common theme between artists, scientists and also engineers – the intimate relationship between understanding and creation. It is precisely this relationship that becomes evident in a range of works at the intersection of art and science.

An astronomer who takes pictures of the night sky using a telescope might describe them as a depiction of reality. But since usually these images are composed of different pictures and frequency spectra that are then transformed into visible light, they are actually not just images, but also constructions of reality. On a much smaller scale a physicist might produce computer simulations of particle collisions in order to predict there outcome. Even though these simulations are based on sophisticated mathematics, before one compares them to the real world, they are all construction. Another example of constructions in science are the computations and visualizations performed in the field of artificial life. Based on simple rules of evolution, computers are used to perform calculations inspired by the development of simple organisms. While this is heavily inspired by biology, the organisms they depict are entirely constructed. One could say they are not even simulations, but mere metaphors. The resulting dynamic pictures are not about anything in the real world – only metaphorically so. But they are fascinating

constructions of what life could perhaps be like. Finally, at the other end of the art-science spectrum, there is the piece "L'impossible" by the American artist Man Ray depicting cogwheels arranged in a way that makes it impossible for them to move. It has been argued that the underlying theme of this work of art is the proximity and distance of art and technology. It poses a question that we would like to better understand as well and where the FEAT project is positioned. The importance of constructing artefacts roots in a deeply human way of interacting with the world. As human beings we have two fundamental ways of dealing with the world. We are trying to understand it and we are trying to control it. This seems to be fundamental in human nature. Once we understand something, we very often deal with it in language and through the creation of certain things. While linguistic endeavours obviously help us make sense of the world, there are also works of art that have a similar aim. The aim to control the world on the other hand is supposed to save us from a destiny that we seem to be unable to escape. In order to predict nature, we create theories so that we can eventually control it. These are very basic ways in which humans deal with the world and the associated processes of creation underlie a lot of our artistic, engineering and scientific efforts that we see today, but they really point beyond mere art, science or technology – the point to what it is that makes us human.

## The Question about the Limits: Art / Science Collaboration and Cutting-edge Technologies

*By Univ.-Prof. Dr. Ingeborg Reichle*

Why are art and science collaborations so important today? One answer could be: Because within the intersection of art and science urgent epistemic questions about art/aesthetics and/or live/ontology can be negotiated.

What is art? One of the main questions that aesthetic ontology has postulated and has tried to address from the point of view of general ontology, that is, from the question about being. The reflections that philosophy has done about this question (for analytic aesthetics the leading question has been: "Which are the artworks?") has been central to think about the possibilities of art regarding the way in which it corresponds itself – or not – with a certain way of being of reality.

But reality is nowadays constructed in the realm of technoscience and not only in an empirical level, but also in a transcendental one. The production of art is related to technoscience not only because of the use of cutting-edge technologies – and recently of biotechnologies – in its making, but most importantly because in this relationship a model from which to comprehend and interpret reality emerges. Therefore, the question what is art should be posed in the light of an ontology that deals with technoscience and the production of reality within biotechnologies.

What is live? From an epistemological point of view a limit, boundary, or parameter is what enables something to exist; a biological entity, for example, can only exist — and develop and evolve — within certain parameters. Limits, then, are an ontological matter, which allow us to think in terms of shapes and figures, morphologies, transformations, and even names. Life only comes into being in the presence of certain limits, regardless of their flexibility and enduring capacity to change. The fragility and the power of life lie within limits, boundaries, and parameters. However, this issue does not only concern biological limits, for example, within what framework is life possible? Further, there is the question of conceptual limits, models of knowing, epistemological boundaries, and so on. Life is also a concept — a concept that has changed dramatically due to the advent of biotechnology within the frame of technoscience. To reflect on these limits, from biology to philosophy and art (such as bioart), we seek first and foremost to propose arguments about what life is within the flexibility of the limits that we are currently experiencing in connection with technoscience. Here, not just science but art, too, has an important role to play, because throughout history art has been a human activity that constantly configures and refigures the limits of the sensible world. During the twentieth century science and technology acquired a dominant role in redefining the concept of life. Technology-driven science and research rendered the basic physical and functional unit of heredity, the gene, accessible to human manipulation, thus turning biology into technology. The genetic code and computer code became interchangeable,

opening up new possible constellations for designing the biological sphere. This groundbreaking development went unnoticed in the art world: it was not until the 1990s that artists began to make increased use advanced technology to explore and create new art forms, such as digital art or hybrid art and even bioart. Science-based art emerged, enhancing progressive encounters with science and technology and shifting the terrain of art towards cutting-edge technologies and the technosciences.

When art turned to the technosciences this obviously made it necessary for artists to get acquainted with new epistemologies and a new logic of producing reality within the techno-scientific regime. By bringing their artistic endeavour with cutting-edge technology to the public's attention, science-based art has provoked greater reflection on the limits of manipulating and/or creating life with biotechnology, highlighting the new genome editing technologies like CRISPR and new approaches in the field of synthetic biology, which are cheap and easy to use and are on the point of revolutionizing the question about the ontology of life. Therefore, it is high time to shed some light on the relationship of ontology and aesthetics in the age of technoscience by focusing on the production of art that is related to technoscience; not only because of the technologies it uses — but most importantly because from this relationship a model emerges which is fruitful for understanding and interpreting reality.

## The poetics of Innovation – Knowledge in Art and Technology

*By Prof. Dr. Mark Coeckelbergh*

Epistemologically, the usual idea on how the process of design works is that first there is an idea and a concept followed by the execution of said concept and in particular the materialization of an idea. But first we need to ask ourselves: What kind of knowledge is there in innovation and can a conception of knowledge be retrieved that refers to a less purposeful or in any case less controlled process of making and creating? What could be different understandings of technological innovation? Such a conception could help to bring technology and art closer together. The ancient Greeks often put episteme (theoretical knowledge) in contrast to techne – the latter being a more concrete activity, a craft like medicine or music. While techne focuses on the human intention, physis looks at what happens in non-human nature. Poiesis, on the other hand, lies in between poiesis and techne. It is about bringing forth or letting happen; it is an action that transforms and continues the world. German philosopher Martin Heidegger refers to it as a "bringing-forth". He described poiesis as "the blooming of the blossom, the coming-out of a butterfly from a cocoon, the plummeting of a waterfall when the snow begins to melt". But in contrast to non-human nature, this process of "bringing-forth" doesn't happen in itself. It happens "in another" – in the craftsman or the artist. This type of understanding of techne and poiesis can also be applied to what we know today as art. In this context, the artist doesn't express him or herself, but something reveals itself within the artist. The craftsman or artist is a participant and the material also actively participates in this process opposed to being "dead matter". As Hagberg describes it: "The artist discovers the meaning of (the) work in the materials of the medium, rather than infusing the materials with significance through the embodiment of an artistic intention."

These concepts can help to look at innovation and art in new ways. Innovation is not so much about design, but also about bringing-forth. It is dependent on human participants, but human beings are merely a part of it. Innovation is then not so much about the mind or genius of the designer but rather a process in which humans and non-humans participate. So like art, design can and must be re-thought: it is about letting something come through, emerge. As a society, we must ask ourselves how we can create more space for these different kinds of epistemic-material processes and different kinds of innovation. Research and innovation policies should at least leave room for – and preferably encourage – less "design" oriented thinking. This "poeticization" cannot be done by merely adding a "poetic" layer at the end; it requires a transformation of innovation processes and practices. Generally, there needs to be more room for different approaches and different kinds of thinking, not only in art, but also in science and innovation.

*Break-out sessions*

The workshop participants were split up into four thematic groups matching their interests and

the FET projects they are collaborating with to further discuss process and aims of art-science collaborations. The following passages give an overview of their conclusions.

*Group "bio"*
The participants concluded that after the digital revolution, a biological one will be the "next big thing" with game-changing develop-ments in fields as bio-technology, synthetic biology, and so on. The question is now: How can artists and designers be more embedded in these fields? One the one hand, art can help balancing the public opinion which is often influenced by false stories that are painting a rather negative image of the possibilities offered by life-sciences. But by creating artworks that find their way into the media, they might also be able to change the way policies are made.
As artists have a lot of expertise in navigating multiple disciplines that are generally not perceived as going together very well and as they are experts in managing chaos, they can have a positive influence on the often very messy world of science, where a lot of research is cumulated that will shape our future without actually knowing how this future will look like at first. Generally, it was pointed out that it would be necessary to facilitate longer art-science collaborations with increased funding in order to bring stability to these projects and enhance the results.

*Group "quantum"*
The group reached the conclusion that there is a reciprocal process of understanding between artists and scientists. It is not just the artists joining the scientists in the lab and trying to gain understanding of what the scientists are doing. There is a reciprocal process in which also the scientists are trying to gain insights on what the artists are doing, what methods they use and how their artwork is fitting in within the overall framework of the art world. Both artists and scientists are looking for that which cannot be predicted. Not knowing what result they are looking for can make the process of collaboration mutually beneficial for artists and scientists. The challenge of looking for the unforeseeable can be described as the nucleus for the reciprocal understanding between artists and scientists. A common interest is important for the success of this process. It should not just be one side answering the questions of the other. As for the nature of the collaboration, different models were discussed. There is the option of a full residency as opposed to several lab visits. Also, the work process itself could either be based on discussions or based on mutual practice (e.g. building something together). Both models are represented within the FEAT project. The timeframe of the collaboration is another issue. While FET projects generally last between four and five years, the residency is restricted to less than one year. The impact of the collaboration however might only be perceived by the scientists several years after the it has ended.

*Group "robo"*
The group focused on the differences and similarities between art and science. As they were originally united, it seems problematic that today they are always seen as separated. Generally, artists and scientists were described as having the same aim – to create and give life to something new. Interdisciplinarity is seen as a way to fuel inspiration both with artists as well as scientists. The funding systems and all its constraints were generally described as difficult to deal with and art could be able to guide a way out, but on the other hand it could also get increasingly sucked up by the system and get locked in a kind of "obsessive compulsive disorder".

*Group "time"*
The participants pointed out, that the whole collaboration process needs to be regarded as part of the artwork and suggested to have the option to deliver not only the final piece of art but also a representation of the process that led to it.
When combining art and science, putting them on an equal power level was seen as important for the success of the collaboration. The arts and science were described as having a shared responsibility of giving the public an understanding of scientific results. At the same time there is of course a value for both the artists and the scientists involved in the projects as well. They can gain new perspectives on their work, recognize values outside of their own environment and be more objective in their work process. A composite way of thinking is another part of the collaboration's outcome. The participants concluded that in order for art and science to challenge each other and to enable further hybrid outcomes, more art science interactions need to be facilitated.

# Workshop Result Paper 2

*FEAT @ Ars Electronica*
*Linz Workshop - JUNE 8th 2016*

A panel of experts from art, science and research policy discusses challenges of art science interaction in future research programmes.

Participants: Ralph Dum (EC), Luis Miguel Girão (EC, Artshare), Špela Petrič (artist), Erich Prem (eutema), Andrea Wald (Austrian Science Fund FWF), Thorsten Schumm (nuClock), Christophe de Jaeger (GLUON)
In cooperation with DITOs—Doing it Together Science, togetherscience.eu.

## Artist Interventions and Interviews

In these six sessions, the audience was introduced to intermediate results and given an overview over the artist's experiences so far and their work in progress. Each presentation was followed by a reaction by an expert of the field or a scientist involved in the project the artists are collaborating with.
Anna Dumitriu - interviewed by Annick Bureaud
Having worked repeatedly with bacteria and infectious diseases, the MRG-Grammar project (that aims to devise a new strategy for deciphering the regulatory rules of gene regulation) was a natural partner for Anna Dumitriu. Out of the six partner institutions of the project, her first impulse was then to collaborate with the scientsts at Technion – Israel Institute of Technology who are working with bacteria. But when attending a project meeting in Heidelberg, Dumitriu also met a scientist from the Segal lab, which is a pioneering lab for microbiome research. As both institutes are based in Israel, the idea of a split residency with these two institutions took shape. After seeing a presentation about the work done at the Sanger Institute at Cambridge, where scientists are working with mice to understand the immune system, the artist also decided to pay them a visit, gaining a deeper understanding not only about the immune system's reactions to infections, but also of genetics in general.

On the ideal form of art/science collaboration, Dumitriu stated: "The longer you can collaborate with someone, the better. I have been working with some scientists for over 15 years. Over such a long period of time, you can really develop a language in the subject that you are working with. Even for shorter collaborations, it is important to not be limited to a very short timeframe and specific location. You need to be able to come work with the scientists for a while, then go back to your studio to develop more on your own and then revisit the labs." Concerning FEAT in particular, Dumitriu expressed that in an ideal world, the artists would be brought in in the development stage of the project to be part of it throughout the whole venture.

## Vicky Isley & Paul Smith (boredomresearch)

*– interviewed by Alex May*

Boredomresearch are known for creating simulations on natural behavior and movement. At FEAT, they are working with subCULTron, who are looking to establish a community of robots in a heavily polluted environment. Spending a couple of weeks in the artificial life lab at Karl Franzens University Graz, they were confronted with the challenges and restrictions of building physical things: "We had to get over the fact that, in contrast to our simulations, we can't change the physics of the universe and that we just need to find solutions", said Smith, "and in the course of working with an electrical engineer we found a space between art and electrical engineering which we call 'Visceral Engineering'."

After learning that the subCULTron team did some of their initial tests in jam jars, Isley and Smith were intrigued by the concept of using household waste, especially in relation to our current environmental situation, and decided to start building robots out of human plastic waste. In the course of testing the motion dynamics of micro controlled plastic rubbish, their robots would start losing their synthetic tendrils to end up swimming in a plastic soup of their own remains which would get trapped in their propellers and ultimately interrupt their life cycle. Through this process the artists realized

if they built these robots into an installation they wouldn't be able to return to their base anymore to get charged and their robots would die - suffering the same fate as a big amount of the world's marine life. The artists are keen to explore this element in their work, producing a "death sequence" – a last gesture that the robots could make as they realized that their fate is doomed. In the dialogue with their collaborators at subCULTron Isley and Smith realized that they had touched on some kind of taboo from an engineer's perspective – robot death. A topic that boredomresearch themselves have thus far only touched upon in some of their previous artworks in a subtle manner.

Being interviewed by Alex May, Isley also gave some insights into the reciprocal inspiration processes within their collaboration project: discussing how the subCULTron team were keen to engineer robots with more of a biological signature; experimenting with other synthetic materials in their robot designs and how the artists seemed to have inspired them to explore this further.

## Evelina Domnitch & Dmitry Gelfand

*– interviewed by Jurij Krpan*

Evelina Domnitch and Dmitry Gelfand are collaborating wth RySQ, who are developing quantum simulators with Rydberg atoms. While this is a quite complex endeavour, they decided to bring a relatively simple device to demonstrate it. Ion traps use dynamic electric fields to trap charged particles. Domnitch and Gelfand plan to build their own ion trap, but while scientists usually create a vacuum around it to limit interferences, the two artists want to rather realize their project with lycopodium spores and microspheres. When these spores are trapped in the electric field of the ion trap, they begin to oscillate and they - as one might put it – dance. This dance is actually the visualization of the electric field and Domnitch and Gelfand will shine a laser on it so that it becomes brightly visible. In the long run the two artists are also planning to utilize this effect in a citizen science project where people can bring samples of air from different regions to be put in the ion trap in order to visualize what "lives" in the air. Jurij Krpan then started his interview confronting the duo with a very basic question concerning their project: "When you work with scientist, what are you bringing to the table?" Dmitry Gelfand then elaborated: "We believe that the physiology of the senses and elasticity of human perception is such that it can be tuned to grapple with this immense philosophical problem that we haven't the faintest idea what occurs on the fundamental scale. We have some hints about reality, but at the bottom line we require some calibration or tuning. There are no more imaginative or fertile means to do this than through art." Evelina Domnitch added: "Why do humans engage in science? To create better technology or to create methods that allow human beings to develop? I think art and science are there for the same reasons: to allow human beings to evolve. The main issue is not inspiring the scientists, it is bringing this knowledge to a broader public and tuning the minds of the audience. I am very happy that some artists have the courage to approach scientific discourse because there is this horrible misconception in the general public that science is so difficult that you can't understand it, but in fact we have science to make things clear and we have to share it with the rest of humanity."

## Miha Turšič

*– reaction by George Beckett (scientist, INTERTWinE)*

Miha Turšič and his partner Špela Petrič are collaborating with INTERTWinE in the field of exascale computing. The project addresses the problem of programming model design and implementation for the Exascale. In this field, that is relatively unfamiliar to them, the artist duo first started to dig into some core questions: How is science made and knowledge produced? Is the science we are dealing with really absolute, can we trust it? Dealing with the invisible materiality of supercomputing they started to be more interested in the process and less in what is produced. They soon came to the conclusion, that supercomputing research comes from a consensus between scientists and politicians. Turšič: "While scientists are eager to expand knowledge, politicians supporting it deal with a narrow scope of preferred directions e.g. priorities."

Moving forward, the artists started to question the precision of scientific results. Visiting the European Centre for Medium Range Weather forecast, where weeks or even months of weather forecasts are

produced, they investigated the precision of those results and found out that 50 different models and three-hour old data were being used. Asking the scientists what the weather was right now the artists got 50 different answers that were more or less correct but didn't really represent the present moment. "This is something that artists are dealing with: Trying to present our subjectivity in the present moment. We came to the conclusion that with this scientific methodology and using these scientific simulations and computation we can really not get to that subjective precision" Turšič remarked. Other questions the artists are dealing with in their current collaboration, visiting several facilities with supercomputers, are how and why to use supercomputers and in the end: what are they really? The duo is digging into their materiality. Recognising the sounds and smells while visiting the research centres they even thought of reproducing exactly those.

Picking up on the questions of subjectivity and absolute truth George Beckett asked: "Do you see the challenge of precision in supercomputing as something more than what scientists traditionally have to deal with and is it something that they have to be fully conscious of to derive useful output?" Turšič: "Since we come from art, we really care about this subjective relevance. What does it have to do with us? Especially in the case with the weather predictions: on one side you see a huge machine producing huge amounts of data and understanding, but in the end you get a very basic information. We really question: how is this relevant to us? What is the value of this final output? In the end, as a person, it is more relevant what you experience, not the information you get. There is a potential to be more precise if you include subjective perception to this data. Can we include some "social noise" or "individual noise" into the final equation and get more precise or valuable information out of the supercomputing process? That is where we see an opportunity in this collaborative process. All of these machines are so dedicated to such important issues and we asked ourselves: can we use artistic algorithms? All these computers use so much powers and they are so expensive, but can we afford doing an art piece on these precious computers? Could we run something so simple and subjective as an art algorithm on them? This is where we would see our contribution." Špela Petrič added: "What is really interesting about high performance computing is not necessarily only what is done in the scientific context, but actually how it connects to deep data, deep learning and a lot of processes that are running in society that might be a bit invisible to us."

## Ruth Jarman (semiconductor)

*– interviewed by Ralph Dum*

British artist duo semiconductor (Ruth Jarman and Joe Gerhardt) are collaborating with QuProCS whose goal is to develop a new radical approach to probe complex quantum systems for quantum simulations, based on both quantification and optimization of extractable information. The duo has worked with scientists in many different fields before and their first engagement with quantum physics was at CERN particle physics laboratory in Geneva where they were first confronted with the complexity of the field. They are interested both in the matter that scientists are working with and the techniques and processes that they develop to understand that.

So far, semiconductor have visited two of the seven institutions involved in QuProCS and are still in their research phase. As their work is very visual and audio based and the realm of quantum physics is quite difficult to try and understand let alone create an experience of, the artists are now trying to create their own interpretation of quantum physics. One line of thinking that they have been exploring is how to create their own quantum computer generated simulations. While they are of course not trying to calculate quantum simulations, as you would really need a quantum computer to be able to handle the amount of information and the complexity, they are interested in creating their own 3D generated models that have the characteristics of a quantum system in them to then combine these with the tools being used to represent the computational simulations. This is only one of many ideas that the duo is contemplating. "We want to explore these theoretical models and the computer simulations as tools and language and are interested in revealing the human signature within them as a way to understanding what man brings to nature. Are we experiencing nature or science? Is science just mediating nature?" Jarman explained.
Asked by Ralph Dum about what she thinks scientists would expect from interactions with

semiconductor Jarman concluded: “I think expectations have changed over the years. When we first started working with scientists, they were very puzzled about why we would want to work with their data, but they would kind of go along with it. To the point now where a scientist at QuProCS approached us being very excited about the collaboration and particularly about using our work to explain their science. But that is not quite what we are doing, and it also is a kind of pressure, but it takes a while for these relationships to emerge. Sometimes even until long after the collaboration has ended. While the scientists would often like us to come in at the end of the project, it is very important to us to be involved from the beginning and also to go in not knowing everything about the science yet, but learning it from the tools and processes that they are using. This enables us to interpret it in a different way and to have a different viewpoint.”

## Kerstin Ergenzinger

*– reaction by Simon Stellmer (scientist, nuclock)*

Kerstin Ergenzinger is working with the nuClock consortium, which is developing a scientific clock that reaches a much higher precision compared to the best clocks that are operated today in some of the world’s finest laboratories. In her work, she is very much focussing on processes of perception and finding ways to make our own personal perception perceivable to others in a certain way. To demonstrate her project, she brought a modified string drum. Being a work in progress it was a functional model, not yet an aesthetic one. Among other materials, nitinol wire was used, which is a robotic wire that contracts like a muscle when being heated up and expands again when it cools down. It can be controlled in various ways and has both kinetic and sonic qualities – for it swings in the communication frequency of the chip you control it with. Ergenzinger has used the material in several installations before in her endeavour of making perception perceivable. She does this by creating situations and phenomena that call for adaption processes of our different human senses, for example using the ability of scaling down, to then slowly experience noise as a multiplicity of different sensory phenomena, something one normally tends to miss in a world where we are often confronted with noise that overexcites and covers our receptivity.
Concerning her collaboration with nuClock, the artist stated: “They try to make an even more precise clock by using the nucleus instead of the atom itself since it has an even higher transition frequency and therefor an even higher resolution of time. So it is actually kind of opposing my interest in making ambiguity precise. That makes up for a very challenging and open-minded confrontation. I would really love to create something that has to do with movement and contains reflections on time on very different levels.”
From the view of one of the scientists from nuClock, Simon Stellmer commented: “As of now we are trying to find a very weak and faint state within the nucleus that is surrounded by a lot of noise. This really connects to Kerstin’s work. Within all of this noise we have to extract very small and faint signals that lead us towards a state that we later want to use for our clock. The drum that we look at here will be one out of many. There will be a cloud of drums, all of them producing noise. By navigating within this cloud of drums we can than make them resonate or emit a signal that is meaningful depending on the position we are at. Right now we are still in a very open phase, where we have a lot of different discussions and are open to all kinds of ideas and we are very much looking forward to developing some novel piece of art that is leading both Kerstin and us out of our comfort zones.”

## Round Table

This session, in collaboration with “DITOs – Doing it Together Science (www.togetherscience.eu), addressed funding programmes and the question “Where should we go from here?” concerning the funding of art/science interactions and art funding in general. The participants were: Ralph Dum (EC), Luis Miguel Girão (EC, Artshare), Špela Petrič (artist), Andrea Wald (Austrian Science Fund FWF), Thorsten Schumm (nuClock) and Christophe de Jaeger (GLUON). The Round Table was moderated by Erich Prem (eutema).

Erich Prem: Looking back at EU programmes like STARTS bringing together science and art – what has been achieved so far and what hasn’t been achieved?

Ralph Dum: What has been achieved is actually that

the idea has been put on the funding landscape. It wasn't clear until we started STARTS that anybody would consider the arts as a viable means of achieving innovation in Horizon 2020. What has not been achieved is to really immerse artists into our framework programme. The vision would be that at the very conception of the project and the proposals people think about the art as an integral part of any innovation process that leads to jobs and growth. To put forward the idea of the arts as a catalyst for new products and new developments. At this point this is still missing, but we only started three years ago.

Erich Prem: Thorsten Schumm, from the point of view of the scientist, why bother to collaborate with artists?

Thorsten Schumm: When you ask us, your scientific grant should be required to contain not only a dissemination component but really an artistic component which in my point of view goes beyond dissemination to the general public. We would start doing this already in the design of the consortium. It might influence how the consortium will be set up. This should be the order it should be done in. It should be a viable part from the beginning and it should be evaluated how well it is done or how interesting or inspiring it could be. I also think interactions with artists can give us feedback back into the research and to the scientists that are doing it. We are forced to view things from a new perspective and the actions and means are investigated by someone who doesn't take everything for granted and hasn't gone through the same machinery as we have. There is definitely a stimulus.

Erich Prem: Luis Miguel Girão, what would you expect from the funding side in the future, what needs to be carried on and where is there still room for improvement?

Luis Miguel Girão: I believe that the ground to start doing things that are significant and relevant is there. Now it is up to our community to deliver something that is significant and relevant. And I believe in order to do so, we have to go beyond illustration of ideas. It cannot just be about dissemination. We have to make clear to the commission and other institutions that artistic practices generate knowledge just like scientific practices. We have a new generation of artists who are more tech-savvy and who have great scientific knowledge.

Erich Prem: Since you mentioned knowledge, I think we have to ask Andrea Wald here: You are in charge of a programme that interacts with the arts. Maybe you can say a few words about what you have been doing in the past and what you think about this idea that knowledge doesn't just arise in science but also in the arts.

Andrea Wald: At the Austrian Science Fund I work for a small programme called "PEEK". It is a programme for art based research and actually works the other way round. PEEK starts from the artist and this comes from our believe, that science as well as art does some sort of basic research. What we are funding with PEEK is not art as a project but art as a method to explore new perspectives on art and the world. We believe that art or artistic exploration can actually find blind spots in research objects that are also looked at by other sciences and that they can actually work together. We start from an art based research methodology and then the artists bring in all kinds of other scientists at their disposal. So we really have a very interdisciplinary project.
Erich Prem: Špela, as an artist you have some experience with artistic funding sources and these sort of engineering science funds. Does it make a difference to you?

Špela Petrič: In a way I think science is actually still a part of society that does get more funding than the arts and I think it is very important to also channel more funding into this very important part of society. I think that the fear of most artists who are going into partnership with the industries is that we somehow would have to produce works to the taste of the engineers or scientists. As we have done several of these collaborations before I can say that to us personally this fear has not yet come true. Perhaps also because we are standing our ground. Another great benefit from this sort of funding is that automatically you are offered access which otherwise can take months. Going from institution to institution begging to be heard and for the scientists to have the time for you. The willingness of the scientific partners to collaborate is included in the package which is great.

Erich Prem: Industry was mentioned, Christophe

de Jaeger. GLUON, which you are in charge of also makes an effort to connect with industry. Can you perhaps elaborate a bit on this and what you would expect from the future? And if I may add: Can't they really pay for it themselves?

Christophe de Jaeger: For GLUON it was a kind of challenge for me because we have not been funded by the government in the beginning and I had to go into the market and try convince industrialists that working with artists in their R&D departments was interesting for them. This was very difficult since industrialists don't really know what contemporary art is in general. Let alone that they understand what we do, that this is also a form of art. So we created a collective of industrialists in Belgium and we started to travel with them and visit artists' studios where the artists were allowed to explain their work to them. Slowly but certainly they started to understand what the value would be for them or their research. That was the beginning – to convince the industrialists. The second step was to find the resources in order to get enough funding to start working within the R&D departments of the companies. For the future I hope there will be some kind of public private partnership between the cultural and the economic government in Belgium so that the cultural government can say we will pay for example the fees of the artists so that they can spend six months within a company. Because, while the companies always fund the expertise and the materials, it is difficult to convince them to pay the fees. So public private partnerships would be very important to what we do.

Erich Prem: When you read the texts of programmes there are at least three objectives when it comes to art/science collaboration: Science communication, knowledge and industry which might go more into the direction of design and innovation. Do you think that is right? Is that not overloading the art/science collaboration? What should we do in the future? Christophe de Jaeger: Thinking about objectives I think you can't organize something like objectives. There are so many industries and so many artists with different ideas. I always liked what Billy Klüver did when he was working for the "Experiments in Art and Technology" programme in New York. He organized a big fair where the researchers from companies and research institutions were presenting their research to the artists for them to learn what the scientists did. I think that a programme like STARTS should invite many people and make a big effort to invite both industrialists and artists so that they can see what each of them are doing in a very unorganized way. I think great connections could come out of this.

Erich Prem: Ralph, from the point of view of the Commission. Do you agree that these are all the objectives that you are supposed to fulfil or can you focus on just some of them?

Ralph Dum: Well these are three objectives for three different programmes. As you know we had art/science programmes for a long time and they were mainly about dissemination and communication. I think this was a viable goal and it has been a viable goal for thirty years. To have art as an ingredient in the knowledge creation and programme development process is a new idea. One that is often contested from both sides. So I think it is an interesting idea, but it needs further development. From the arts side I've heard there is this fear of being instrumentalized. From the technology side there is the conviction of irrelevance of the art world. You have to bring these two different convictions sort of to a clash and you will probably see that they are wrong. It is very different to say artists are there for dissemination, for explaining research to the general public or to say that the artists are an integral part of the development process. I don't think this is the same level of funding and certainly STARTS is of the second type.

Erich Prem: Thorsten, you have been shaking your head. What do you think about this?

Thorsten Schumm: I am not shaking my head in opposition, I would just like to add something. First of all, I would like to say that already science has many faces and forms and I think art/science collaborations will have even more faces and forms so it is hard to define gatekeepers that can all be fulfilled by all of these types of collaborations. As you said some will be more on the dissemination side, some will be more on the "critical questioning side" evaluating the impact of science on society and so on. What I do not entirely agree with is to say that the scientists don't bother and they only bother if they have to, because their science funding may be coupled to an arts programme. That may be

true on a high or intermediate level, but I think in a bottom up approach it really works. The researcher who needs the artist – that always functions. There is a strong willingness. Why there is the impression that on the institutional level this is not the case I can only speculate, but I hope this can be overcome quickly.
Ralph Dum: We are here preaching to the convinced. I was giving a presentation in Manchester a couple of weeks ago together with some parliamentarians and in the end I got two questions. The first came from a lobbyist for start-ups and he asked: "Why do you invest in artists, why don't you put the money into start-ups?" So the conclusion was: why bother about artists? The second question came from an artist, because I always bring up the iPhone as a good example for a collaboration of the art world and the industry world and the artist said: "Why would artists contribute to the iPhone which pollutes the world?" It was this typical European way of saying "well there is technology, which is dirty and there is art, which is useless". I think there is an issue of silo thinking in Europe and I think if we don't overcome that then we will have a hard time getting further with STARTS.

Špela Petrič: My question would be: where do you actually manifest the work? For example, we have now a residency which will result in artworks. Where will these artworks be shown? Is this for a gallery? Is this something that we should be more manifesting within these institutions to get the most out of these collaborations? Like you said, in a one on one situation there is always something happening, some chemistry but then I would say that most of this chemistry is lost on peers even in the institution who pass you by for months wondering what you are doing there.

Erich Prem: Can I just ask. because this is something that interests me as well, which comes back, and I am sorry, to this citizen communication in part. Very often, art is elitist. Not in what it does but in the kind of people it communicates with. It happens in galleries, in art spaces that are theoretically open to everybody but not in practice. Now science is even worse because it is truly elitist. Now we combine these two – what do we get? On the other hand, there is Ars Electronica and you could probably argue that this is certainly not elitist. Luis Miguel, I am asking you because you are a researcher as well as an artist so you are also in the middle. Is this an argument pro or against or maybe is it good to be elitist because we are targeting people with money?

Luis Miguel Girão: Well, I think you put it brilliantly. I think it is quite true what you said. If you ever hear me praise elitism though, please call my doctor because I think elitism leads nowhere in principle. It might be a need of the human race to be led and then you might conceive that, but in principle I don't think it needs to be supported because it exists at such and is a way of the strongest coming together. What I think is interesting to look at is, that this integration of artistic individuals might lead to an openness on both ends. Because from my perspective what happens is that on both ends it is very difficult to reach a sustainable way of practicing. For artists it is very difficult to enter into the big market of the galleries and the big cultural centres because the way the loop is designed is exactly in the way of containing these new introductions. The same is happening in science. So I believe that because of the artistic nature of wanting to change the world, new doors might be opened. From the point of view of artistic history, we are doing no more than expanding what our predecessors from movements like Fluxus were doing. Already back then they were trying to get out of the galleries and bring artistic expression to real live. Look what happened after that. What are the museums and cultural centres doing with this legacy? Not much because you can't do much with that, right? But there are a number of artists who are, knowingly or not, moving into this direction and I really believe that programs like STARTS can from an artistic perspective be a way of understanding why and how artistic expression has a real impact on society and economy.

Christophe de Jaeger: Well I think that for the art world this elitism really exists. I work for a centre of fine arts and this centre was very conservative. There was no art and science department and the newest thing that they had was photography. But slowly I tried to convince the directors that science and art is something interesting to look at. The director will also be coming here tomorrow and slowly he also starts to change the whole policy of the centre for fine arts. For example, he will create a lab structure where people are invited to discuss and show projects that are not finished. He is even thinking about changing the way you make exhibitions.

He says from now on all the exhibitions should be creations. So he will invite artists working with new technologies who also work on the foundation of the exhibitions that will come to the centre for fine arts and augment those exhibitions or experiment with the way you present the exhibition to the public. So I think this is a very good example for how fast the art world is changing now. The rift between the world of art and the world of science is becoming smaller.

Erich Prem: I would now like to open the floor to questions from the audience.

Jurij Krpan: What I think the discussion today, but also in general is lacking is one structural point: We are speaking about art and science which are social activities. We are speaking about artists and scientists who are individuals. Sometimes we are speaking about laboratories and scientific institutions. But very rarely we are speaking about artistic platforms that are providing environments which can protect artists. We are one such platform and are very heavily interested in artists not doing science, but art. And probably the scientific institutions are interested in scientists doing science, not art. However, they should work together. So like it is the case here at Ars Electronica, we are here to translate between both. We can facilitate the communication between the two. So it is very important, that we are establishing these environments where the discourses and co-working processes between scientists and artists can take place. Because it is not only about galleries. It is also about labs to facilitate production. So platforms like Ars Electronica are very important for these kinds of productions to happen.

Erich Prem: Any reactions from the funding agencies? More platforms in the future? Infrastructure funding?

Ralph Dum: I agree. If you talk to industrialists then they tell you, that whenever relations to the art world worked it was because there was some missing link between the art world and their engineers. So you don't take the artists and put them into an engineering team, there needs to be some kind of communicator. Mercedes for example has a communicator who will be here today who really insists on this fact that there needs to be a buffer between his engineers and the artists who should contribute to the future of transport in Mercedes for example. Ars Electronica is a wonderful example for a missing link, for a translator. Indeed, in STARTS we were thinking of a platform and there will be an online platform, but it is not so much in the sense of Ars Electronica it is more in the practical sense of having a database of artists and of industrialists and bringing them together. But you are right, this interaction needs to be moderated in some sense and I think this is an important aspect.
Andrea Wald: Within the PEEK programme and at the Austrian Science Fund in general we are actually forbidden to fund infrastructure, that is something that has to come from the institutions as such, which is a pity, but that was actually a new law that was implemented, so we don't pay overheads anymore that were able to be used for infrastructure. So what happens within the PEEK programme now is that any type of infrastructure, any type of platforms or workshops that are established, normally take place within art institutions like artist spaces or universities. When it comes to universities focused on technologies, they also host quite a number of events and they also sometimes serve as what we call national research partners so they provide infrastructure as well, but we see that most of the interdisciplinary work that is taking place within the PEEK programme is actually taking place within an artist environment. There are some applicants who are seeking to change that who really come from a natural science background and are trying to implement the artistic structure there as well. This has not been that successful yet, but it is an exciting endeavour.

Luis Miguel Girão: I would just like to emphasize this notion of the platforms, but I think even more relevant is the need to invest in production, in making. Because if you look into the models of funding of artistic practices, artists mostly look for galleries or exhibitions as a source of money to keep doing whatever they do, which is creating. So actually it doesn't make sense that the actual act of creation is not funded and it is very difficult to be funded. In this sense, what is relevant is that we have to find a way so that artworks are considered outcomes of research just like a paper is considered an outcome of research. We will never play a significant role in the research world if artworks, exhibitions and all of the outcomes of artistic practices are not recognized as a concrete outcome. Because they are concrete outcomes. This I find

extremely important. I still don't know how we are going to do that, but we will work on that.

Lucas Evers: Luis Miguel, can you say something more concretely about how we achieve that everybody sees that the production of artwork is knowledge production as such? Because that also has to do with science politics. Whether science allows this to be regarded knowledge. In order to get a piece of the cake there, to get towards making production funded.

Luis Miguel Girão: I think we have a window of opportunity. There is a revision in the making. The EU will try to unify research outcome, because now they are actually different from country to country. In some countries artworks are actually understood as scientific outcomes. Now, in the process of unification, we might be able to bring this idea to the table and achieve this for all EU countries.

Andrea Wald: This is also the case in Austria with the PEEK programme. That actually makes a huge difference for us as a funding agency because for example we acknowledge artworks and exhibitions as part of the track record and you don't have to have a masters or PhD degree to apply for the PEEK programme and be eligible for post doc funding for example. This would not be the case if PEEK were to be part of the other programmes at FWF.

Lucas Evers: Do you also have a lobby towards heritage institutions like museums that take a big junk of the cultural money that is available, that some of that money should go towards artwork production?

Andrea Wald: That is an interesting idea, but actually I am not aware if this has been subject of discussion yet.

Lucas Evers: Well I would like to bring that in as a subject of discussion. In every European country we see that funding decreases for individual artist production and small artist collectives, but that the funding remains intact for all the museums with their nice buildings, shops and huge budgets to buy pieces from the market that have been already bought with black money.

Andrea Wald: That is something that's fairly new at the Austrian Science fund to bring in external money because we used to get all our money just from the ministry of science, which has been changing slightly.

Lucas Evers: If you talk about post-disciplinary collaborations, you should also break down these walls between science funding and museum funding I would say.

Erich Prem: I actually wanted to save this discussion until the very end, but now that you brought it up: it is very early, but there will be a new framework programme. I am asking in particular the panel members with EC background: Do you think you have the right support already to continue these activities, what is your strongest selling argument, what would you need, how can these people here help in changing member states opinions? Or maybe do you already have enough support?

Ralph Dum: First of all, I should say of course, that in the commission we are separated in different directorate-generals and there is one that is education and culture. It is supporting art, the creation of art and also museums. I have nothing to say about whatever policy they adopt. All I can say is that money that is devoted to the arts is coming from this directorate-general for education and culture. So if we put money into art in a directorate that is supposed to be creating the future of technology for Europe, then of course there has to be a return on investment to technology if you invest into arts. Otherwise there is no way of justifying money that was given by politics to technology to be suddenly spent on art.
So I guess there has to be a willingness to accept, that whoever is funded as part of these technology programs has to be contributing to technology. There is a certain reluctance to accept that, but I think once this reluctance is overcome, there is a great willingness at least on our side to really invest into the arts as a means of production, of making technology more human centred, of using art as a means of social innovation and I guess this principle is accepted. Whether this principle translates into funding is another issues. This is of course where member states come in and it depends largely on who you talk to. Obviously a ministry for culture will be more interested in funding this than a ministry for technology. But again: I think that funding

for the arts in a technology programme has to be justified and you have to show what's in it for technology. This is the main problem that we have in STARTS because this of course brings certain issues of instrumentalization and issues of loss of independence that come up whenever you argue with cultural committees.
Erich Prem: Thorsten, can you support this?

Thorsten Schumm: You asked the question whether we are ready for the next framework programme. The scientist in me would say that we get a lot of administrative support, so I think we are quite good at navigating all the funding schemes on the market. All of that works as long as we do excellent research. Then it is just up to lobbying and sales arguments. The problem is once again infrastructure. Especially in experimental physics we need machines and devices, not just manpower. We really need lasers and labs and infrastructure and what not. If there are no means to get this, then we will start falling behind and that is what is troubling us from a purely scientific perspective. There has to be a solution there somehow.

Annick Bureaud: I was just wondering: how do you evaluate and what are your criteria for return on investment when you spend technology money on art?

Ralph Dum: Well, technology is not a goal on its own. It is a means for society to progress and I think a lot of what art can contribute is indeed in helping technology become useful for citizens. I think that is where the art world can contribute and where it could be evaluated if it can contribute. So I am not pleading for a "technology for technologies' sake" argument. We fund technology for the future of Europe. So I think it is at this link of technology and society, where the arts can contribute and should contribute. By making technology useful for humans. Smart cities are a good example. If you look at it from a technological point of view it is nothing else but a bunch of sensors that you put everywhere and humanity is happy. The reality is different. You need somebody who makes this technology acceptable and useful for the citizen and I think it is here that I see a lot of reasons why art can be beneficial for technology. I am not sure whether this answers your question?

Annick Bureaud: This is a huge discussion because you also need philosophers, sociologists, anthropologists, designers and all sorts of social scientists to answer how you can make technology fit within a society and then at the bottom level you have to find what is good for society. I think this is a very delicate and sensitive topic for which you need much more time than an afternoon at Ars Electronica. But, this is something that is very interesting and art could be one of the mechanisms telling you if you are going into the right directions.

Ralph Dum: But you see, to have anthropologists, psychologists, designers in the loop is generally accepted. We have an enormous amount of programmes which are called science and society. So there is no issue here with anybody. You of course need humanities to make technology more human. So nobody doubts that. What is still rather rare is to consider art as a means to do that and I guess with the STARTS programme, which is a very small programme, we are talking about peanuts compared to what is invested in other areas. We want to seed this idea of the arts as a valuable contributor to these ideas.

Luis Miguel Girão: You were asking how we could help and I guess that the best way to help now is to deliver. Because now these small peanuts of money are there, but they were not there before. I see this as our chance to prove that actually it is reasonable to bring artists into this field. Which means that if we come as newcomers, as new players into the field of research and we are going to deliver what other people do – namely reports and things like that – we are doomed. Because what we have to prove is that we are lighter, we are more agile and we can very easily and adaptively bring in new applications and new ways of developing technology. And I think that there are new calls coming very shortly for residencies, for new projects in the context of STARTS and I strongly believe that these are the projects that need to be very concrete and bring something that is very consistent material, that is different from what has been done before.

Evelina Domnitch: I am very much with you, because we want to act and we are ready to act and know where we go. What I would like to say is that indeed art has been marginalized from society. If we look into more ancient societies, we see that art is the

mother of science. Through alchemy, science was born. So art was the glue of society, it was how people came together and what is important to me in these collaborations is that we are not looking at artists or scientists. It does not matter whether you are a scientist or a cleaning lady. We are all in this ride on spaceship earth together and art was this lubricator, this common mental field. Whether you come together to sing, to dance, it doesn't matter. Now, art has been marginalized. For example, our environment is shaping how we think. It used to be nature, now it is architecture. Our buildings were conceived by artists, today they are functional. Today all the reality we go through is extremely functional. Normal people don't have theses avenues or platforms to practice art. When we come to work with scientists in a scientific institution, a very great benefit is that we interact with students. We are told that students show great progress after working with us. So education is a very important part. In science, the big problem is working in different domains and not bringing the whole picture together.
So I hope that artists and scientists working together can look more critically at reality and can have more comprehensive views. I think artists should be brought as these kind of actors for communities through the platforms into all kinds of fields. Into industry, into how we design buildings and interactions. It is a daunting task. The reason I am inspired by science is because there is this thing called turbulence that we completely don't understand and as scientists we cannot describe turbulence. That is where all our simple equations break down. Turbulence is this kind of self-organization of a very complex system where all of a sudden from disorder comes order and coherence. So I think artists are needed to create this kind of coherence in society and just basically bring us humans together. It is very difficult, but in the past our ancestors managed to do that and that's how social progress was achieved. There is a great imbalance today between the art that is practiced, that thinks about today's problems and big museums that are cemeteries for old art, that are basically banks that possess huge amount of money. If we look again at the history of humanity, the artworks are the most valuable possessions that we have and we need to take a little bit of money from the museums and give it to the artists who work today so that the van Gogh of today does not commit suicide.

Erich Prem: So we have the museums of the past, the science and technology for the future and the galleries of today.

Jurij Krpan: I wanted to put what we are now trying to structure into the right words and I would like to answer Annick's question: Why art and not anthropology or other scientific practices. I am understanding the correlation in production in art, science and technology. I would say that science is producing knowledge, while art is producing meaning. So when they meet, the scientists can better understand how their knowledge influences society. How the product that engineers will create will change our society. We are trying to invest this distinction between design thinking and art thinking. Design thinking, integrated at the beginning of the project, is where you see the possibilities and you creatively and methodologically try to find different solutions. This is how designers are working. They are proposing solutions. While artists in their "art thinking" are proposing new questions and opening blank territories where new answers need to be produced. This is why we, in our days of consumerism, are facing a lot of products whose dead end we can already envision now. There is a lot of bullshit being produced. But by involving artists to create meaning you can envision how the society can react and this can help making decisions in order to create better products. An artist can do what cultural workers cannot. Philosophers can also produce meaning. However, what they do is that they are developing meaning in a linear way, while artists are addressing your senses and can go even deeper and open your fields.

Lucas Evers: That would mean also the rethinking of what return on investment is in those sorts of programmes and what impact is. So we should rethink economic impact and return on investment. Then you really create a place for meaning production.

Christophe de Jaeger: I would not be too much against the museums. You say we are banks, but I think at museums there are lots of people who do intellectual work. It is some sort of research that delivers inspiring stories and I think we should be productive. If you look at the STARTS programme: It will be the Victoria & Albert Museum, it will be Centre

Pompidou, it will be big institutions. And now is the moment where we can use them to tell an inspiring story. And I can tell you that bringing in these big institutions and stopping this big rift that has been there since the 70ies, to include them in the STARTS programme now that they are interested is fantastic and it will really inspire industrialists and their researchers in their R&D departments. It will inspire rectors at the universities and I think it is something extremely important that we have the institutions with us. Museums as production entities – I think this could become extremely interesting. It is true what you were saying, they should not only be the banks and mostly it is like that, I fully agree. But we can open up museums to also show the story of the researchers, what they have learned from the collaboration. So that we not only show artworks, but what their profit was from the collaboration with artists through videos and other things. That they show the indirect results of working together with artists. Because we always think of direct innovation and direct products, but there are a lot of indirect things going on and the museums can show this. They can make big publications; they can contribute a lot.

# Colophon

FEAT partners some of Europe's most innovative scientists with artists working at the cutting edge of technology, to create a productive atmosphere where participating artists will learn new skills and work with novel materials while scientists gain new perspectives and learn new ways to make their work public.

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Cover image: 'Robots in Distress ' by boredomresearch

Top image page 31: Viral interventions (detail).
The Hunt for New Antimicrobials was funded through the Artist in Residence Scheme 2016 of the Centre for Chronic Diseases and Disorders (C2D2) at the University of York. The scheme is supported by the Wellcome Trust [ref: 105624] and the University of York.

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Scientific research is a collaborative affair. Teams from across academia and industry work in partnership to solve problems and test new methods. What goes on in this building is a testament to the interdisciplinarity required for ground-breaking research. We are now half way through the European Union's major research programme – Horizon 2020 – which is allocating €80-bn to research that aims to strengthen the EU's position in science, foster industrial innovation (ensuring technological breakthroughs are developed into viable products with real commercial potential) as well as research that addresses major social concerns (such as climate change and renewable energy). The six works of art in this exhibition are directly the result of EU-funded research into new and emerging technologies, which seek to solve diverse problems from carbon capture to monitoring pollution.

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