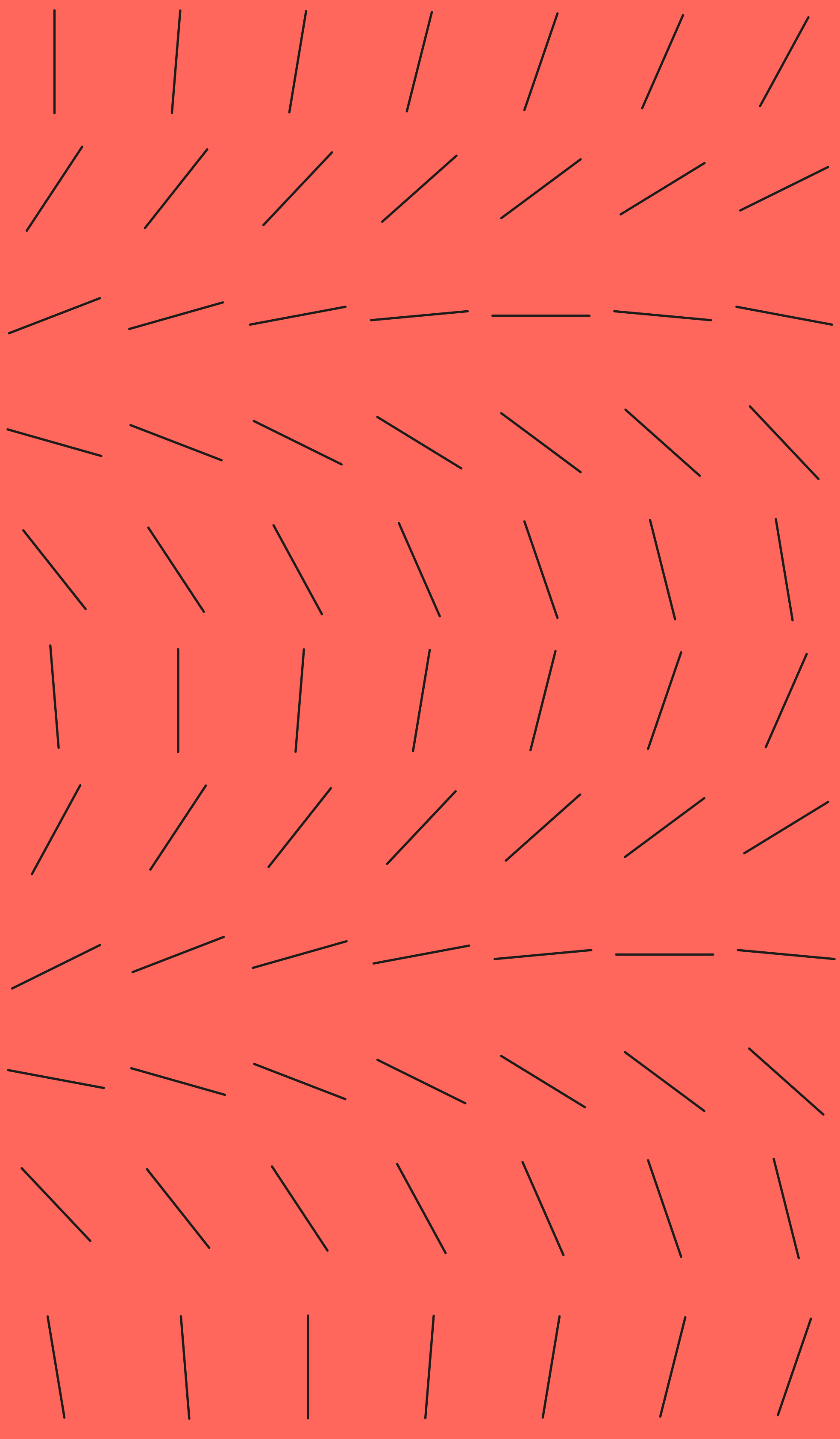
SONIC ACTS XV

~~THE DARK UNIVERSE~~

Edited by Arie Altena/ Sonic Acts



THE DARK UNIVERSE

Edited by Arie Altena
& Sonic Acts

Sonic Acts Press

INTRODUCTION

Unknown, incomprehensible, mysterious, un-illuminated, gloomy, bleak, catastrophic. All of these are implied by the word 'dark'. *The Dark Universe* takes its title from the fifteenth Sonic Acts festival, held in Amsterdam during the first two months of 2013. The lectures, works, films, events and performances at the festival explored a variety of aspects of our unknown universe and the state of our planet, and this collection of essays, interviews and images complements and extends the festival theme.

The starting points for the theme 'The Dark Universe' are recent developments in science, which suggest that our universe and world are more unfamiliar and much weirder than we ever imagined. Because our senses are limited – our human senses only perceive a fraction of the electromagnetic spectrum – we have developed an array of instruments to extend our capabilities and detect radiation across the entire spectrum, from gamma to radio waves. Using the Planck Space Observatory, for instance, we are able to study cosmic background radiation at a very high resolution, looking back to the birth of the universe. In 2012 the Large Hadron Collider detected the 'missing' Higgs boson, a fundamental part of the Standard Model of particle physics. But what these immensely advanced instruments record is probably only a small part of what is there. Data from astronomical observations can only be explained by postulating the existence of large quantities of matter and energy that we are unable to see or hear, and that we have not been able to measure directly. In all likelihood only 5% of all the matter and energy in the universe is made of ordinary matter. The remaining 95% is completely dark to us – it is 'dark matter' and 'dark energy'.

Occupying ourselves with things we don't understand is a deep-rooted human characteristic. Both the arts and the sciences have always been at the core of our exploration of the unknown, the strange, and the unfamiliar. Artists and scientists repeatedly rethink reality and question the things we think we know. Hence Sonic Acts brought together scientists, artists, theorists and musicians to explore the boundaries of our knowledge. They function as guides to a dark universe and a dark planet, and investigate how, in a metaphorical sense, a work of art can function as an instrument to translate the ‘unperceivable’, and can be an instrument to imagine ‘dark matters’.

The book follows a trajectory from the unknown universe as explored by physics and astronomy, to the outlook for humanity and human society on our planet. Along the way artists tell how they investigate phenomenological reality and the dark spots in our sensory apparatus, and there are visual ‘data essays’ by Bitcaves revealing yet other aspects of the dark world we inhabit.

After the visual essay ‘From the Darkroom’, which uses stills from experimental films to sketch a portrait of a dark universe, the collection opens with an essay on current research in physics and astronomy by Michael Doser. The contribution by Anil Ananthaswamy about the ‘edge’ of physics, shows some of the instruments used to conduct research. This is followed by Roger Malina’s essay about the advances in data collection in astronomy, and an extensive account of the early history of radio astronomy by David P.D. Munns. A more philosophical and critical stance towards the unknown is found in Andrew Pickering’s essay on cybernetics and its ‘ontology of the unknown’. Simon Ings contributes a short, sharp and almost burlesque text that touches on Lenin’s and Stalin’s short-sighted admiration for science.

The conversations with the artists, who all displayed works in the Sonic Acts *Dark Universe* exhibition or performed in the festival, provide insights into how they work with signals, soundwaves, radio waves, colour, vibrations and other electromagnetic phenomena. Raviv Ganchrow’s essay delves deeply into the phenomenology of sound and the research underpinning his sound piece *Fray*. An older text by ‘non-philosopher’ François Laruelle poetically connects the theme of colour perception (raised in several interviews) to the pitch black of outer space. George Dyson takes a radical non-human approach when he talks about the origin of the digital universe, its concept of time, and about how algorithms are ruling our world. Omar Muñoz-Cremers grapples with the question of where our future went, and the dilemma of retromania. Also included here is Geoff Manaugh’s appraisal of the work of architect Lebbeus Woods and an interview with him.

The book then orbits towards our dark planet, and investigates some of the ominous aspects of our present society. Andrew Blackwell reports on his visit to Chernobyl. In an extensive interview Saskia Sassen explains how she uncovers dark realities that normally remain in the shadows of the global system, and how the financial system is bringing catastrophe to our society. Keller Easterling looks into the development of free economic zones and their impact. Another visual essay by Bitcaves explores this world of dark finance and shadow banking. Brigitte van der Sande focuses on Trevor Paglen’s art and research methodologies, and zooms in on his work *The Last Pictures* and the view of the future of humanity that it embodies.

Can we reinvent or rediscover a future? And what will it look like?

Sonic Acts / Arie Altena

Contents

FROM THE DARKROOM

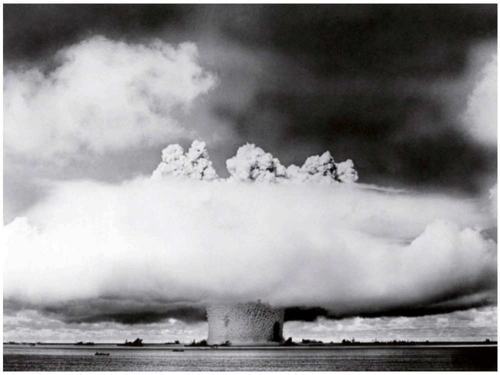
Mirna Belina

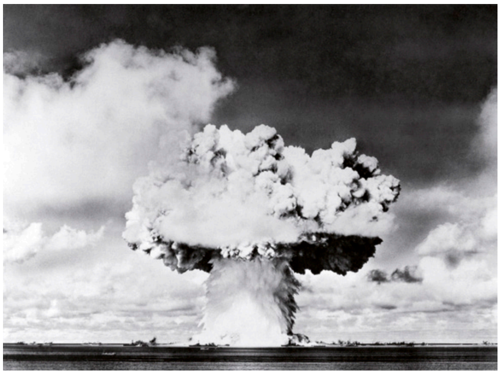
‘The most terrifying fact about the Universe is not that it is hostile but that it is indifferent; but if we can come to terms with this indifference and accept the challenges of life within the boundaries of death – however mutable man may be able to make them – our existence as a species can have genuine meaning and fulfilment. However vast the darkness, we must supply our own light’.

Stanley Kubrick, ‘I really think I’m entitled to an answer to that question’, interview by Eric Norden, *Playboy* vol, 15, no. 9, September 1968.

Soldiers, fireworks, Mickey Mouse, tanks, and dancing naked girls! A collage of Eros and Thanatos erupting in a 2000-image explosion to Ray Charles singing *What'd I Say*. Talk about a cosmic bang! Bruce Conner, *Cosmic Ray*, 1961, 16 mm.

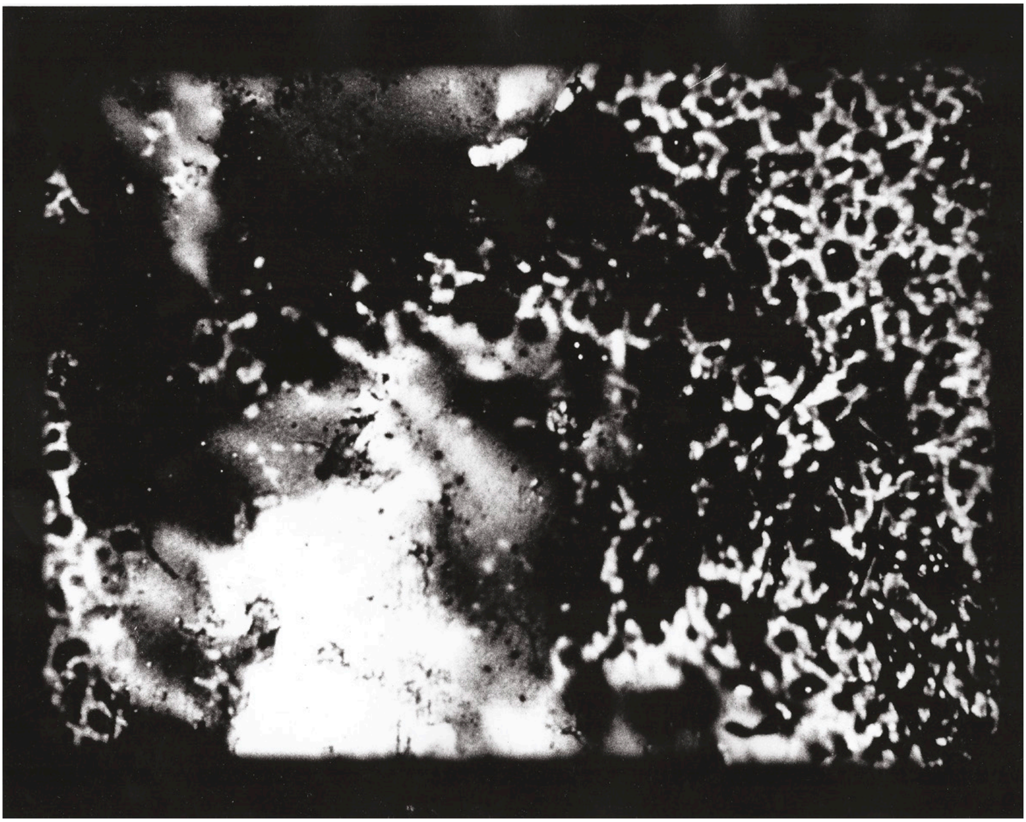
Operation Crossroads, the first underwater A-bomb test, 25 July 1946, Bikini Atoll. We see the spectacle and beauty of the explosion 27 times, while its destructiveness assumes the dimensions of a universal cosmic force. Bruce Conner, *Crossroads*, 1976, 35 mm.





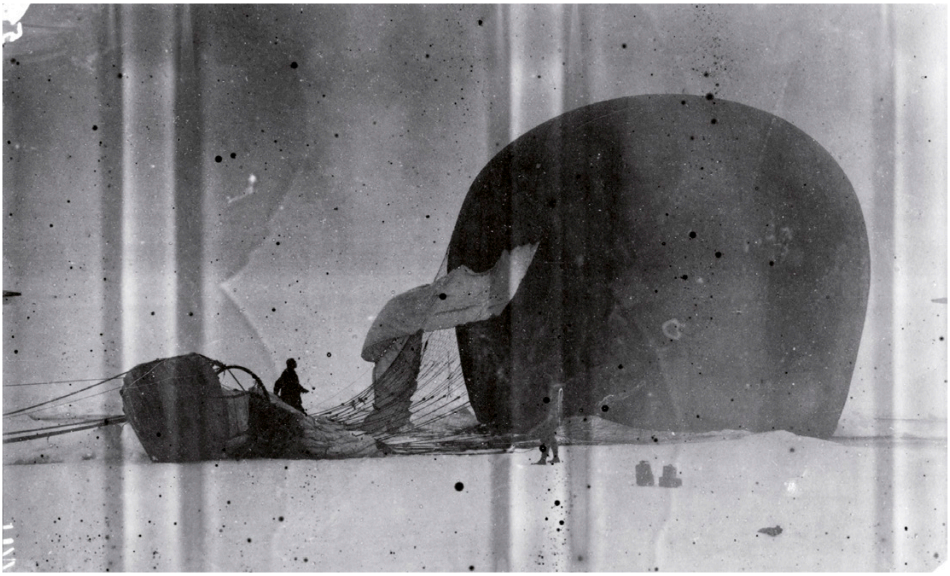
Tokyo, a decaying metropolis pulsating to
the rhythm of its nuclear heartbeat.
Makino Takashi, *Generator*, 2011, film to HD.

The Altiplano region in Chile is an isolated landscape with traces of a dark past: areas littered with landmines and derelict political prisons in the middle of the driest desert in the world. It is a place of magnificent strangeness on the edge of visual abstraction, a sublime vision hidden in a secret dimension of our reality…. The subtle transformations of perception reveal the destructive impact of mankind.
Mihai Grecu, *Centipede Sun*, 2010, HD.



Seed black, seed black, sperm black, sperm black. Aldo Tambellini, *Black is*, 1965, 16 mm.

Destruction of the highest order, visual bombing of film shreds, fragments, ash, dirt and trash. Wilhelm and Birgit Hein, *Rohfilm*, 1968, 16 mm.



Three historical accounts of Arctic travellers in search of the Unknown, from 300 BC to the late nineteenth century. Story told in different shades of white. Anna Abrahams and Jan Frederik Groot, *Desert 79°: Three Journeys Beyond the Known World*, 2010, 35 mm.

'"The collapse of the stellar universe will occur – like creation – in grandiose splendour". The words attributed to Blaise Pascal which preface my film *Lessons of Darkness* are in fact by me. Pascal himself could not have said it better'. Werner Herzog, 'On the Absolute, the Sublime and Ecstatic Truth' in *ARION* vol. 17 no. 3, Winter 2010. Werner Herzog, *Lektionen in Finsternis*, 1992, Super 16 mm.

above – ‘An ancient abstract painting encrusted with rust and sand behind which human faces half-form and disappear, suggesting eons of time and civilizations rising and falling. As the film’s hues metamorphose in tandem with a shifting abstract soundtrack, *PSALM* evokes not only rust and sand but fire, wind and oceans as well, a never-ending cycle of creation and destruction’. Stephen Holden, *The New York Times*, Canyon Cinema catalogue. Phil Solomon, *Psalm II: Walking Distance*, 1999, 16 mm.

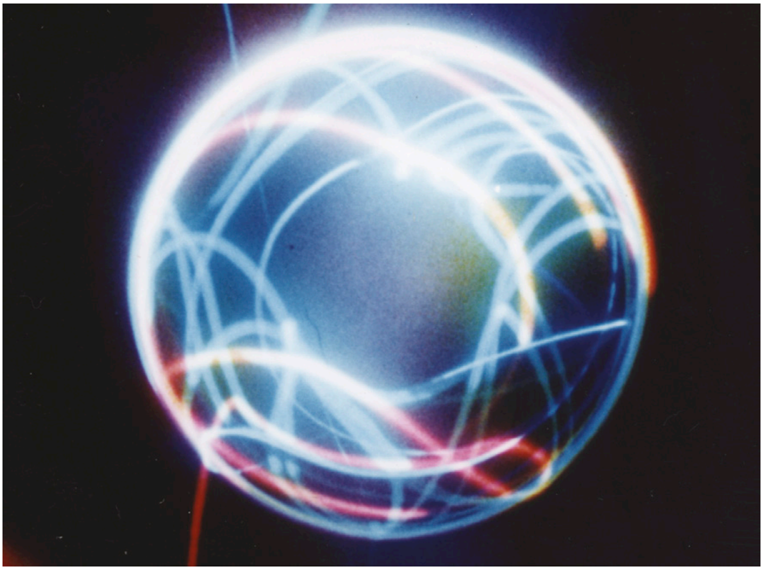
right – A vast and complex system of meanings articulated by each frame of the image. One of them: a deconstruction of the safari that the Austrian tourists asked the director to document. Ultimately, so much more than a postcolonial ethnographic exposé of the brutalities of colonialism. A majestic structure of endless combinations and sync events in sound and image. Peter Kubelka, *Unsere Afrikareise*, 1996, 16 mm.

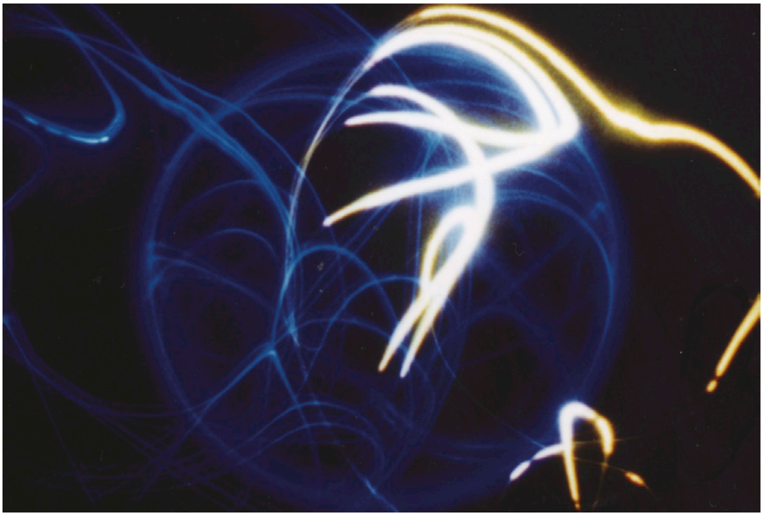
There is a geomagnetic storm occurring in the Earth's upper atmosphere. Solar wind rumbles, captured at the frequency of 20 Hertz by the CARISMA radio array. Semiconductor (Ruth Jarman and Joe Gerhardt), *20Hz*, 2011, HD.

'If you look into darkness you may see the lights of your own retina – not unlike the Northern Lights, not unlike the movements of thought. Like a shapeless accumulation of everything we have ever seen'. Peter Mettler, *Picture of Light*, 1994, Super 16 mm blow-up and 35 mm.

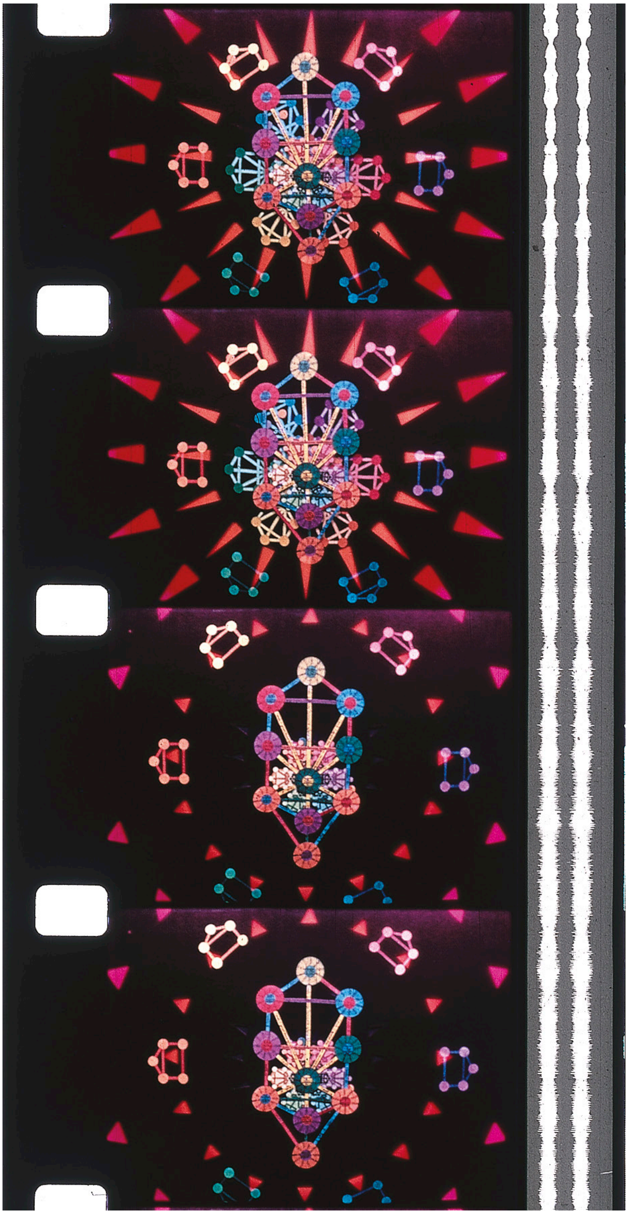
The river sweats
    Oil and tar
    The barges drift
    With the turning tide
    Red sails
    Wide
    To leeward, swing on the heavy spar.

T.S. Eliot, *The Waste Land*, New York: Horace Liveright, 1922.





A film with pure light. Joost Rekveld, #3, 1994, 16 mm.



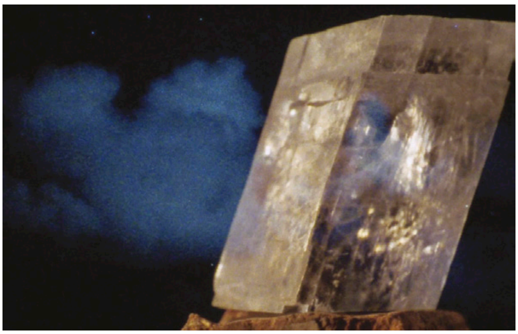
Magical and alchemical cut-up collage set to Thelonious Monk's *Misterioso*. Harry Smith, *Film Number 11: Mirror Animations*, 1957, 16 mm.

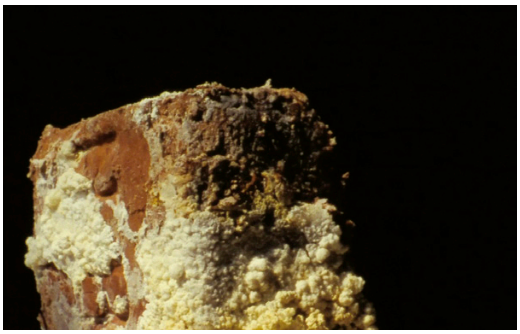
I had a dream, which was not all a dream.
The bright Sun was extinguished, and the stars
Did wander darkling in the eternal space,
Rayless, and pathless, and the icy Earth
Swung blind and blackening in the moonless air;

[...]

                                        The World was void,
The populous and the powerful was a lump,
Seasonless, herbless, treeless, manless, lifeless—
A lump of death—a chaos of hard clay.

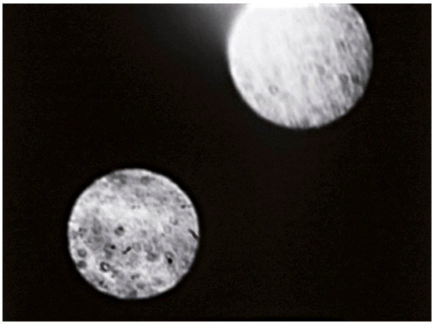
Lord Byron, *Darkness*, lines 1-5, 69-72, first published 1816.





Astronauts on each of the NASA lunar missions took along specialised Hasselblad cameras to take photographs. Though expensive and highly prized, they left the cameras on the Moon to reduce weight for the return trip to Earth. Supposedly, twelve Hasselblad cameras remain on the Moon. Alexander Stewart in collaboration with Peter Miller, *On the Logic of Dubious Historical Accounts, 1969–1972*, 2008, 16 mm (18 fps).

A combination of searing drones with footage of mysterious architectural and natural artefacts. A geologic horror film. Alexander Stewart, *Crusts*, 2011, 16 mm to HD.



A spontaneous *corps exquis*; an abstract dance of light across the darkness of space. Christopher Becks and Peter Miller, *Ritournelle*, 2012, 16 mm.

Image of the universe as it would appear to a voyager in space: into far regions of space, beyond the reach of the strongest telescope, past the Moon, Sun, and Milky Way, into galaxies yet unfathomed.

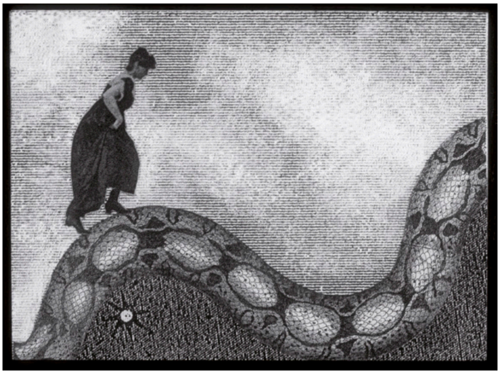
I have seen the dark universe yawning,
Where the black planets roll without aim;
Where they roll in their horror unheeded, without knowledge or lustre or name.

H. P. Lovecraft, *Nemesis*, lines 8–10, 1917.


BUY
Claude Neon

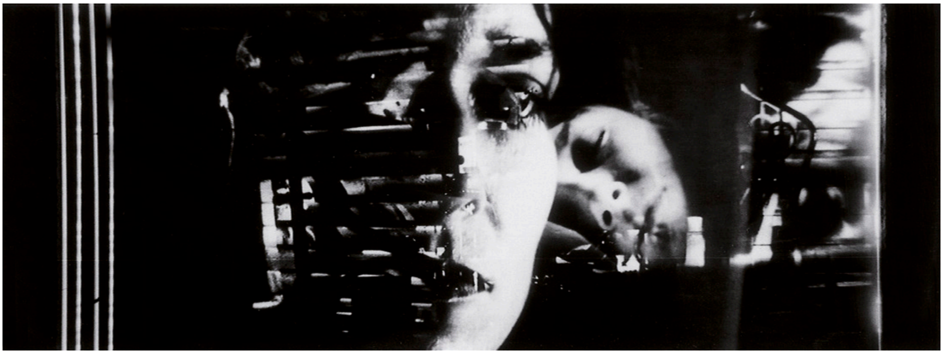

EN VENTE ICI
SCIENCE VIE
éprouve
VRAI FAUX
LA VIE FRANÇAISE
POURQUOI
LES BOURSES
MONTENT
MONSIEUR MARON
MON JARDIN
TRIOMPHE
DES
AILES
MONDE LA VIE
S'ADRESSE
AUX JEUNES
AVRIL
LA VIE DES BÊTES
LA VIE DU M
S VOTRE BIBLIOT
LES ALBUMS...
TRIOMPHE
J'étais
le médeci
COMMENT L'OEIL DE LA T
REGARDAIT LE PREMIER
HOMME DU COSMOS
éprouve
VRAI FAUX
d'Auschwitz
EN VENTE ICI
Sélectio
IOMPH

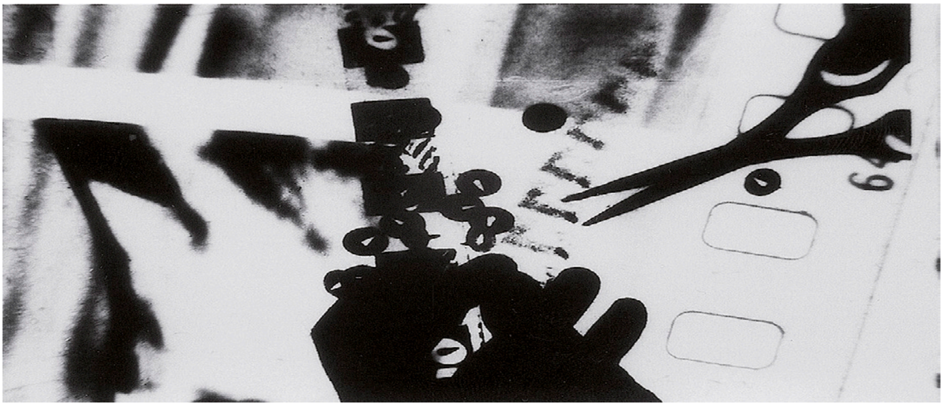
1950s consumerism, popular culture, a world flooded with information, images devoid of meaning, the damage left by war and technological progress… There is a sense of unease and anxiety: the world is speeding up and something is being lost. Arthur Lipsett, *Very Nice, Very Nice*, 1961, 16 mm.

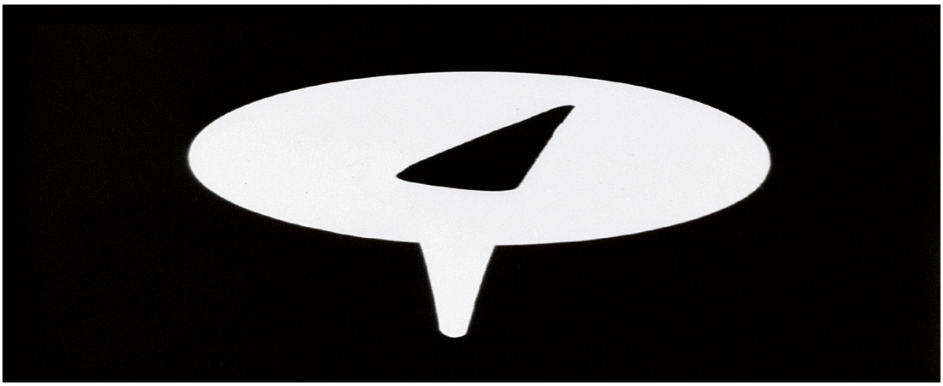


Fantastical journey created from over 4000 handmade collages also incorporating photographs from Eadweard Muybridge's *Human and Animal Locomotion*, 1887. Stacey Steers, *Phantom Canyon*, 2006, 35 mm.

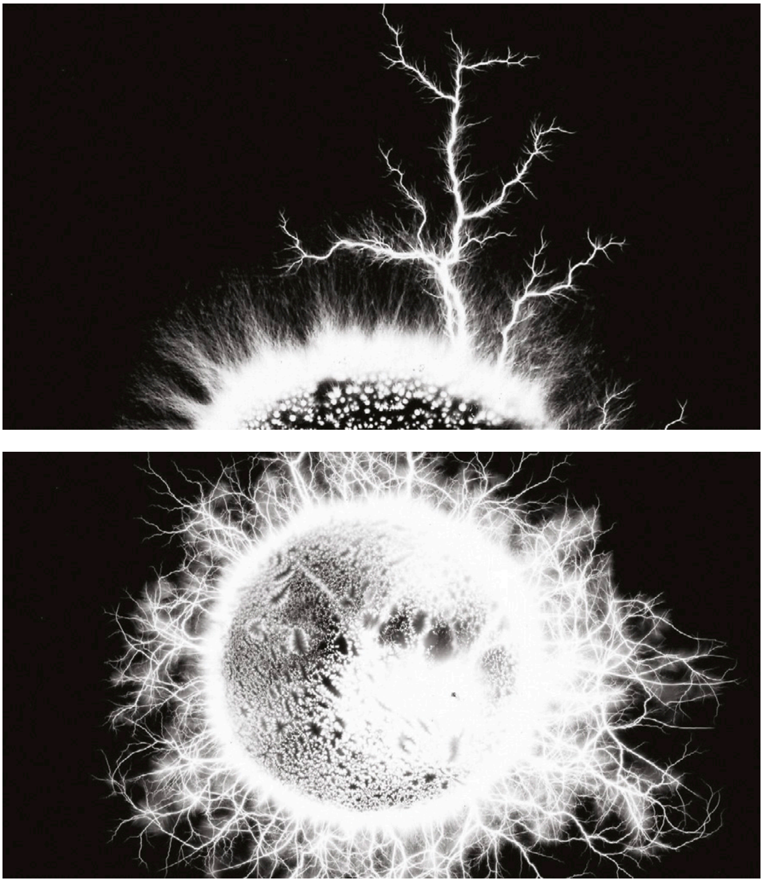
The darkness of dreams, the horror of being unable to escape. 'Behind the awakening lurks the dream. Behind opening doors waits an ego. Behind a man in the room looms the void. The images, the afterimages, the negatives circle each other in a maelstrom in which the classic psychoanalytic view of the conscious mind's unconscious function is gradually lost in a higher logic of neuronal chaos. And then, guided by Man Ray's rayograph technique, they reassemble in a para-dream which – paraphrasing Freud – could be described as a pictorial mental image...' Bert Rebhandl, sixpackfilm catalogue. Peter Tscherkassky, *Dream Work*, 2001, 35 mm.







End note:
The author would like to thank all the filmmakers and institutions that contributed to the visual essay *From the Darkroom*: A. Abrahams, C.Becks, Conner Family Trust, T. Fleisch, M. Grecu, Grimthorpe Film Inc., Harry Smith Archives, B. Hein, R. Jarman, Light Cone, P. Kubelka and F. Camper, National Film Board of Canada, J. Rekveld, sixpackfilm, P. Solomon, S. Steers, A. Stewart, M. Takashi.



Stroboscopic journey into the heart of the body electric.
Thorsten Fleisch, *Energie!*, 2007, HD.

Justine	The Earth is evil. We don't need to grieve for it.
Claire	What?
Justine	Nobody will miss it.
Claire	But where would Leo grow up?
Justine	All I know is, life on Earth is evil.
Claire	There may be life somewhere else.
Justine	But there isn't.
Claire	How do you know?
Justine	Because I know things.
Claire	Oh yes, you always imagined you did.
Justine	I know we're alone.

Lars von Trier, *Melancholia*, Magnolia Pictures, 2011.

DARKNESS ~~LIES IN~~ THE EYE OF THE BEHOLDER

Michael Doser

The Universe we see with our eyes is only a small fraction of what is out there, and what we think should be there, doesn't appear to be. The past two decades have seen many new observations and experimental results that paint a complex picture. In this essay Michael Doser, researcher at CERN, explains the darkness of the Universe.

Darkness lies in the eye of the beholder, and a dark Universe is partly a reflection of our own inability to see the light with which it shines. That it is mostly dark in the small region of colours that we can see is partly surprise, partly physics, and partly biology. The Earth's atmosphere is not transparent to all colours, and it is not easy to build eyes ten metres in size that would be needed to see radio waves, or lead-lined photoreceptor cells to see gamma rays. While looking at the Universe in different colours – from the highest energy gamma rays through ultraviolet and infrared down to ultra-long wavelength radio waves – enables us to construct a rich and complex story, the dark, the invisible and the unseen can tell us as much, if not more, and provide a starkly contrasting picture to the one painted with light.

One of the first surprises is that the night sky is dark. As the astronomer Heinrich Olbers (and others before and after him) pointed out in 1823, in an infinitely old and infinitely large Universe, containing an infinite number of stars, one should see the surface of a star in every direction. Thus the sky should be blazingly hot and bright. That this is not the case proves that this premise is wrong, and is an indication of the non-immortality of stars and of the non-static nature of the Universe. But even a young Universe – resulting from the Big Bang – has the same problem, since the afterglow of the initial event replaces stellar surfaces as the originator of the blazing light. The expansion of space concomitant with the Big Bang reduces the energy of this first light by red-shifting it into the microwave range, where the night sky is indeed shining brightly and uniformly in the form of cosmic microwave background, invisible to our unaided eyes.

By broadening the observed range of light through dedicated and specialised instruments, some on the ground and some above the absorbing atmosphere, and thus observing invisible colours from radio waves to gamma rays, it becomes possible to transform what appears dark into brightly coloured images containing a rich range of information. Such instruments allow mapping out the distribution of Hydrogen (21 cm line) in our galaxy. They chart the distribution of ionised gases in space and around the planets in our solar system in radio waves, and look for objects (cool stars, warm planets such as Jupiter, gas clouds) via their thermal radiation in the microwave and infrared regions. They also look at energetic atoms glowing in the ultraviolet around young stars and in colliding galaxies, they allow us to discover the aftermath of exploding stars in X-ray light, and probe the origins of the most energetic flashes of gamma ray light in neutron stars, pulsars or supernovae.

All this rich detail is invisible to our limited senses, but can be rendered visible by recording the intensities of the colours we are unable to see. Mapping those colours into the visible range (or even into sonograms) has allowed us to build up a complex picture of a dynamic and energetic Universe. It has also allowed us to look back in time, towards remote and barely visible stars, galaxies and proto-galaxies, whose light has been rendered all but invisible through distance and shifted in colour by the expansion of the Universe. Determining the distances to the myriad remote galaxies, and the speed at which they are moving away from our galaxy, is tied in to these detailed multi-spectral observations. Shifts of known colours provide velocity measurements of the brightness of standard 'candles' (stars whose brightness fluctuates in an understood manner or exploding stars of a specific type), and these allow us to measure distances.

While on the human time scale, the Universe appears mostly static, it is in reality furiously dynamic, changing appearances on timescales as short as a few thousand years, and sometimes even seconds, but mostly on inconceivably long time scales. The flow of time itself is invisibly slow, but by looking out across huge distances, all these time scales collapse into a single multi-dimensional snapshot that reveals the present and the past, the nearby structures and the formation of structure, what can be seen and how it came to be.

The picture that emerges is that of great filamentous nets of billions of galaxies, separated by enormous, empty, dark voids. As far back in time as can be seen, there is a network of locally dense clumps of clusters of galaxies separated by vast distances – sometimes billions of light years – devoid of any matter. It looks somewhat like a fine-walled, glowing sponge. And yet this is only a small part of the visible Universe. Many galaxies are too faint to be seen or measured directly, in spite of using the most sensitive telescopes in space. These telescopes stare in the same direction for weeks to slowly build up a picture, photon by photon. And even this picture is incomplete, since it does not contain everything that is now known to be present, including dark matter and dark energy, which patently cannot be seen.

But really, what does 'seeing' mean? If a picture takes weeks to build up, and requires cooled solid-state detectors, signal processing, and remapping of colours, can one still talk about 'seeing'? Or can one extend the concept to pictures that are reprocessed to extract details that are not directly 'visible', but are embedded in the image, as is the case for gravitational lensing? Can 'seeing' be extended to multi-spectral analyses of multiple images, where hypothetical lenses are compared to objects that are detected through the light they emit to discover the distributions of matter that is dark, and thus 'invisible', but whose effects on light through lensing can be discerned, and thus becomes 'visible'? Where instead of using a (gravitational) lens to see a faraway galaxy, the image of the faraway galaxy is used to reconstruct what the lens looks like? If one systematically explores the effects of a set of parameters on simulations of the large-scale structures of the Universe, and then compares those to the ones observed in high-statistics galaxy surveys, can one then be said to 'see' the dark matter that leads to the formation of the same structures in the simulation as those seen in reality?

The difficulty with 'seeing' dark matter is of course that one does not see it. Every observation of it will be indirect: some will be based on distortions of images that cannot easily be accounted for without it; some on modelling, as in the case of structure formation; some on indirect evidence, as in the case of galactic rotation curves, where galaxies rotate – without flying apart – more rapidly than can be accounted for by the visible stars and gas. Consistency across different techniques, however, builds up confidence that we indeed see the same dark matter in gravitational lensing, in colliding galaxy clusters, as we do in microlensing surveys of the cosmic microwave background radiation. This also means that alternate hypotheses – such as modified Newtonian gravity – appear increasingly construed.

But again, it is images that provide the most convincing argument for the existence and the presence of dark matter and of further invisible entities. Measurements of the temperature of the cosmic microwave background have shown that it is spectacularly homogenous across the whole sky. This holds even in regions on opposite sides of the Universe, which have not been in contact with each other since the Big Bang, and have had no time to adjust to each other. This observation in itself indicates that something known as inflation, during which the Universe expanded dramatically, must have taken place, and is the reason why vast parts of the Universe are invisible, in the past, now and forever in the future.

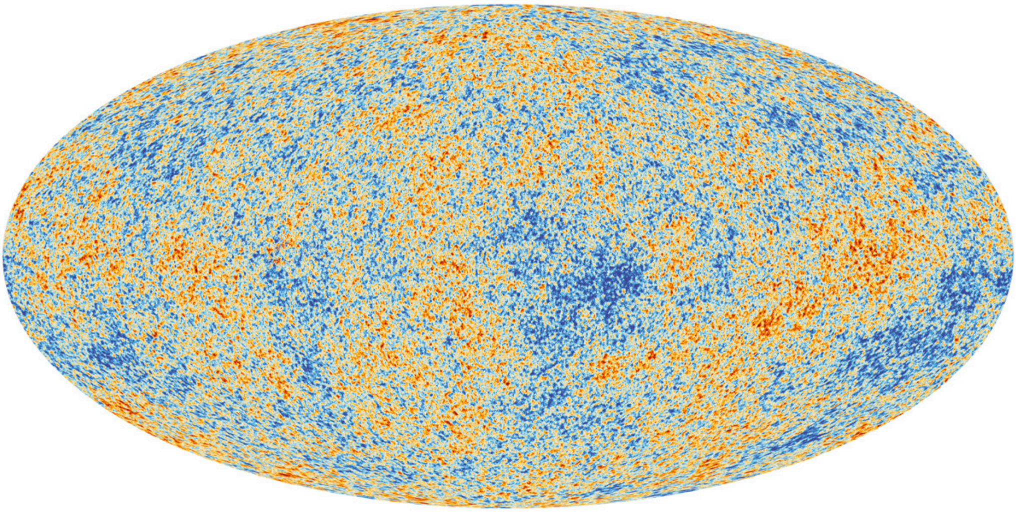
If one goes beyond the homogeneity thanks to highly sensitive measurements of the intensity and colour of the microwave light, minute fluctuations in temperature appear. This speckled pattern of ever so slightly hotter and colder regions (corresponding to temperature differences of hundred-thousandths of a degree) is the frozen image of acoustic oscillations that were governed by the physics of the Universe up to the moment it became transparent, 380,000 years after the Big Bang, and just before the Universe entered the so-called dark ages, in which no stars had yet had time to form. The speckles are not uniformly distributed; some are more pronounced, others weaker, some closer, and others further apart. Indeed, like ripples on a pond, there are characteristic separations between them, they are wavelengths that are a reflection of the physical processes that took place at that time. It is possible to simulate these processes (the model is called the Λ–CDM model), setting parameters like the amount of dark matter, of ordinary matter, of dark energy, the curvature of the Universe, and the amount of time available for their interactions, to work their effects. And the unexpected outcome is that – according to the latest Planck measurements – 70% of all the energy in the Universe is in an unknown form (called dark energy), 25% is in invisible dark matter (of unknown composition), and only 5% is in the form of the matter we are familiar with and understand.

Searches for dark matter have turned up empty handed, eliminating many candidates. MACHOs (massive astrophysical compact halo objects, like large cold planets) have been excluded as a significant component of dark matter. Only WIMPs (weakly interacting massive particles) remain. Of these, so-called super-symmetric particles are prime candidates for dark matter, as they correspond to a fundamental symmetry that has not yet been seen in nature, and which could perhaps be formed in collisions between particles at the highest energies. This could be done at the LHC (the Large Hadron Collider) at CERN in the coming years, if they are light enough to be produced in the most powerful collisions that can be carried out in particle accelerators. But equally, many experiments are attempting to see directly the existing dark matter in our galaxy that the Earth must be streaming through on its annual orbit around the Sun. These range from experiments in the bottoms of mines (looking for WIMPs ricocheting off ultra-cold targets) to outer space (the AMS experiment orbiting Earth is searching for antimatter produced in collisions between dark matter WIMPs).

That matter came together, that galaxies formed, that stars became possible, is a direct consequence of the presence of these thermal ripples, which with their slightly higher density acted like seeds for the formation of structures. But it is also a consequence of the presence of invisible dark matter, without which this coming together would not have happened fast enough to counteract the expansion of the Universe. It is also a consequence of the weakness at the time of dark energy, which did not manage to accelerate the expansion of the Universe until much more recently.

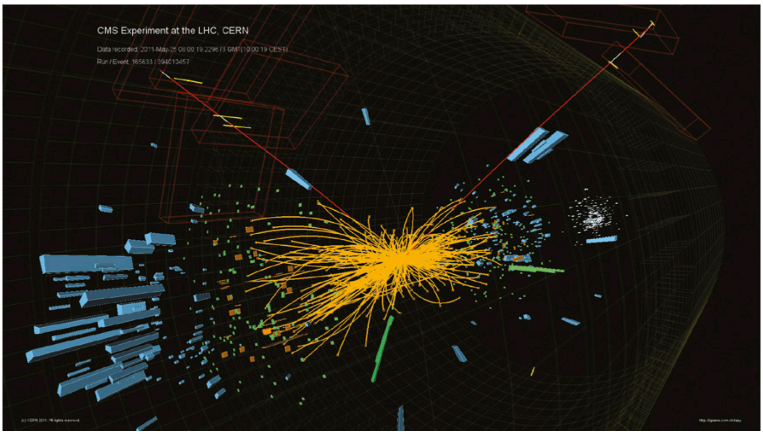
Dark energy is the newcomer on the scene: discovered only at the end of the last century by observing remote exploding stars and finding them dimmer than expected for the distance at which they are (by the measure of their recession velocity). This was confirmed by the ripples in the cosmic microwave background, the formation of large-scale structures and other sensitive probes of the dynamics of expanding space. Dark energy challenges theory and observation (experimentation being difficult to envisage). Why should it only have kicked in at about half of the present age of the Universe? And will it continue to accelerate the expansion of the Universe, or will it fizzle out, dissipate with time or even reverse itself? It will take much observation, imagination and patience before a clearer picture will emerge.

Cosmic Microwave Background as seen by the
Planck Space Telescope, 21 March 2013.



top – The distribution of dark matter, galaxies and hot gas in the core of the merging galaxy cluster Abell 520. The blend of blue and green in the centre of the image reveals that a clump of dark matter resides near most of the hot gas, where very few galaxies are found.

bottom – Real CMS proton-proton collisions events at the Large Hadron Collider (LHC), CERN, in which two high-energy electrons and two high-energy muons are observed. The event shows characteristics expected from the decay of a Higgs boson but is also consistent with background Standard Model physics processes.



While dark matter and dark energy are invisible, but present, another component in the mix should be visible, but appears to be absent. Antimatter must have been produced in equal amounts as matter in the Big Bang, but with the exception of a small amount being produced continuously (in the centre of our galaxy, or above the atmosphere of the Earth, among others), none of it appears to have survived. Antimatter is not dark. On the contrary, it should be indistinguishable from ordinary matter, and it is impossible to tell by looking at the light that it emits whether a galaxy is composed of matter or of antimatter. However, when matter and antimatter meet, they annihilate, and the most characteristic colour in which these annihilations can be seen is that where the energy of the photon corresponds to the mass of an electron, stemming from annihilations between electrons and their antiparticle, positrons. Only the centre of our galaxy shines brightly in this particular colour, and no other source appears anywhere across the sky. That vast amounts of antimatter could have disappeared is only possible if it had been annihilated with the same amount of matter. The Universe is not empty, and this indicates that contrary to expectations, matter and antimatter must have (very slightly) different properties, which would have led to a tiny excess of matter. The source of this has still not been identified.

Experiments probe the decays of particles and their antiparticles, measure the colour of light emitted by atoms and their antiatoms, or measure the gravitational interaction between matter and antimatter. These attempt to discover such a difference, and perhaps understand how half the Universe could have gone missing. From all these observations, the earliest moments of the Universe, its continuous changes and its evolution from its first moments (fractions of a second after the Big Bang) until now can be reconstructed. But it is also possible to extrapolate this evolution into the distant future. Stars are mortal, the speed of light is finite, and the expansion of the Universe appears to be accelerating. In a few billion years, even the nearby galaxies will have disappeared over the horizon. The light emitted by them will not approach us as rapidly as the space between us and them is growing. Only the closest galaxies – Andromeda, the Magellanic Clouds, those that are gravitationally bound to the Milky Way – remain in the vicinity and merge with our galaxy. The distant galaxies will have become truly invisible, and future astronomers will only see our own, alone in an immeasurably large black emptiness.

And then, once the stars formed in the collisions within the local galaxies come to their life's end as well, and star after star either explodes or fades away, the night sky will finally become truly and eternally dark.

THE SEARCH FOR DARK MATTER

Anil Anathaswamy

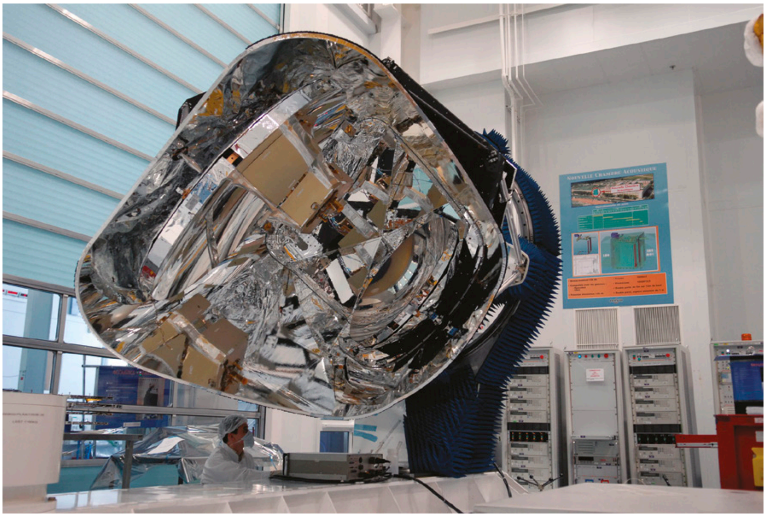
For his book *The Edge of Physics* the science journalist Anil Ananthaswamy travelled to some of the most distant and extreme places where physics experiments are conducted. These are some of the photographs he made during his visits. The photos are followed by a short excerpt from his book, which relates how the research of astronomer Vera Rubin in the 1960s led to the acceptance of the existence of dark matter.

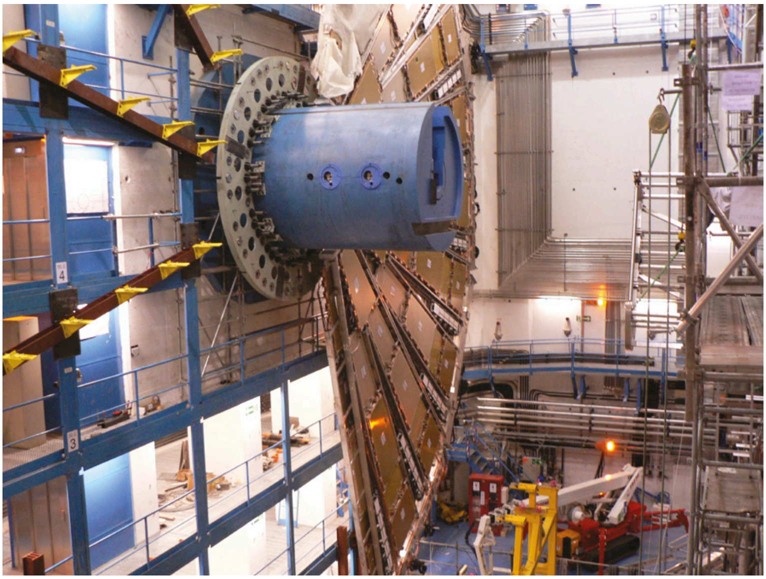
Inside surface hall SXI, looking down into the ATLAS cavern 100 metres underground. The shaft is 60 metres deep, and was used to lower the 7000-ton ATLAS detector bit-by-bit into the cavern below.

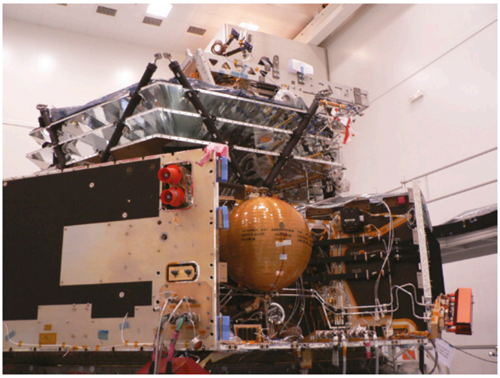
NASA's long duration balloon being filled with helium on the Ross Ice Shelf near McMurdo, Antarctica. The balloon flights carry telescopes and detectors to the edge of the Earth's atmosphere in search of primordial antimatter.

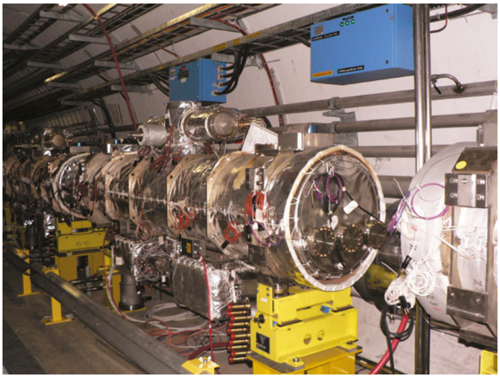
top – The public unveiling of the European Space Agency's Planck Satellite at Thales Alenia Space on 1 February 2007. The satellite is designed to study cosmic microwave background (CMB) radiation with unprecedented precision.

bottom – Assembling one of the ATLAS's endcaps, part of the muon detection system.









top left – The instrumentation aboard the Planck Satellite.

bottom left – A few of the thirteen floors that ring the ATLAS cavern.

top right – Inside the Large Hadron Collider's 27-kilometre-long tunnel. A section of the LHC is being assembled here.

bottom right – The Soudan Underground Laboratory is located half a mile below the Earth's surface. The impressive MINOS cavern at the far end houses a neutrino detector.

A pair of photo-multiplier tubes (PMTs). Scientist Igor Belolaptikov does some quick repairs. This is the 'Ice Camp' on Lake Baikal – the site for maintaining this telescope.

Rubin fell in love with the Department of Terrestrial Magnetism campus (DTM), and one day, now a full-fledged Ph.D., she walked in and asked for a job. (…) In 1965, when Rubin arrived, there were no women on the faculty, and there was a time when even the secretaries were men. But the department hired her as its first female scientist.

Soon after arriving, Rubin nailed the idea that galaxies have much more mass than can be accounted for by luminous matter alone. She was not the first to grapple with the problem of missing mass. By the mid-1930s, Fritz Zwicky had already observed that galaxies in the Coma cluster were moving at speeds too high to be explained by the cluster's observed mass. He reasoned that there had to be more mass in this and other clusters than met the eye, providing the gravity needed to hold the clusters together. But astronomers had never quite taken Zwicky's assertion about unseen mass seriously.

Early astronomers can be forgiven for ignoring evidence of dark matter from studies of galactic clusters, given how difficult it was to observe them with the telescopes of the day. However, later studies of individual galaxies showed that even the best of scientists can be blinkered. By the 1960s, astronomers were measuring the velocities of stars in galaxies by studying their redshifts. But they would study only the inner precincts of a galaxy and then draw rotation curves – graphs that map the velocities of stars as a function of their distance from the galactic center. 'What they would do is draw a Keplerian fall-off,' said Rubin, referring to the application of Kepler's laws of planetary motion to galaxies. These laws say that planets closer to the sun travel faster than those farther away; when applied to galaxies, they require the speed of stars to drop with increasing distance from the galaxy's center – that is, if stars, gas, and dust are the only components of a galaxy. Astronomers simply assumed that, in accordance with Kepler's laws, the velocities of stars would fall off as they moved away from the center, and they merrily drew rotation curves to reflect that assumption.

This was the state of knowledge in 1965, when Rubin teamed up with Kent Ford, a young astronomer with prodigious practical skills. Ford had pioneered the image tube spectrograph, a multistep device in which each stage took photons from the previous stage and amplified the light into ever more photons. The instrument captured light from parts of galaxies so faint that astronomers just looking through the eyepiece could barely see anything there. Rubin and Ford made an unusual but effective team. 'Kent was a magnificent instrument builder, and he knew a lot of astronomy, but once the observations were done he had no interest in the analysis,' Rubin remembers. She would do the analysis and write up the paper for publication (including his name on it, 'of course'), and the paper would sit on Ford's desk for weeks, sometimes months. When pressed to read it. Ford would tell her he didn't have to and that she could remove his name and publish it. She would eventually publish it and keep his name. 'We made a wonderful team,' she said, 'because the instrumentation was really lovely for that time. We were observing things that you couldn't possibly see in the telescope.'

Rubin and Ford started off by observing the extremely faint regions of the Andromeda galaxy, a spiral giant 2.5 million light-years away which dominates our galactic neighborhood. Each night, the duo collected spectra of ionized hydrogen in different regions of the galaxy, far from its bright center. The spectra would show how fast the hydrogen was moving around the galactic core. As Rubin saw the spectra emerge on the photographic plates, she was struck by how similar they all looked. The galaxy was rotating uniformly, no matter how far away from the center they got. Unlike her predecessors, Rubin accepted the data, refusing to draw a convenient Keplerian curve. 'I believed very early on that this was real, and that this was telling us a lot about the Universe,' she said. 'But I didn't know what it was.'

This was 1970. No one quite knew the significance of Rubin's findings, and some astronomers remained reluctant to accept them, even though Rubin buttressed the Andromeda study with similar observations of other galaxies. Her own rotation curves were suggesting that the galaxies had much more mass than could be seen and that the mass stretched in a halo throughout a galaxy and far beyond its visible edge. Then, in 1974, theorists Jeremiah Ostriker, James Peebles, and Amos Yahil, who were all at Princeton University, published a landmark paper that opened with these words: 'There are reasons, increasing in number and quality, to believe that the masses of ordinary galaxies may have been underestimated by a factor of 10 or more.' The paper, along with Rubin's observations, became instrumental in turning opinion around and remains one of the most cited in the history of astronomy and cosmology. Years later, Rubin wrote: 'By 1982, after a decade of initial disquiet, most astronomers reluctantly accepted the conclusion that a galaxy consists of much more than the luminous stars, gas, and dust that can be observed at various wavelengths.' And while the mysterious matter outweighed luminous matter in galaxies by a factor of 10, on the scale of clusters of galaxies and superclusters dark matter seemed to dominate even more. The Universe's unseen mass began to weigh heavily on astronomers' minds.

This is an excerpt from Anil Ananthaswamy: *The Edge of Physics. A Journey to Earth's Extremes to Unlock the Secrets of the Universe*, New York: Houghton Mifflin Harcourt, 2010. Used with kind permission.

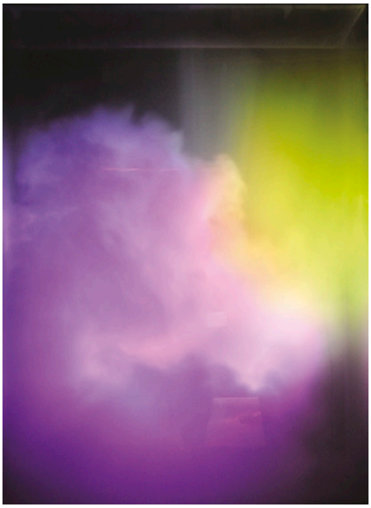
SUPERNOVA (CASSIOPEIA A)

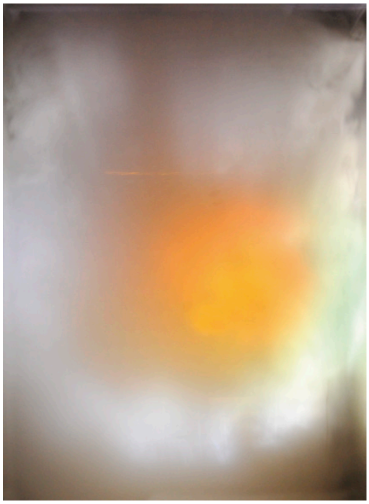
Interview with Félicie d'Estienne d'Orves
Arie Altena

The installation *Supernova (Cassiopeia A)* by Félicie d'Estienne d'Orves depicts an imaginary explosion of a supernova and the birth of matter. Supernovae are extremely luminous stellar explosions that produce a burst of radiation that can outshine an entire galaxy. The explosion expels the star's material and forces a shockwave into the surrounding interstellar space. This interview took place two days before the opening of the exhibition *The Dark Universe*, which featured *Supernova (Cassiopeia A)*.

Arie Altena Supernovae are quite a complex scientific subject matter to make an artwork about. How did the project evolve?

Félicie d'Estienne d'Orves The project started because I met Fabio Acero, a young astrophysicist who works on supernovae. He was studying Cassiopeia A, one the most observed supernova remnants. Supernova is the word for the bright explosion, and Cassiopeia A refers to the remnants of that explosion. The visual aesthetics of supernovae remnants are fascinating. The scientific representations are extremely colourful. The colours refer to the composition of the nebula that remains after a supernova explosion. The colours aren't really there, they are a translation and correspond to different wavelengths emitted by different elements – for instance iron, or carbon – created in the explosion. A supernova remnant creates heavy elements, such as iron; it is a cosmic motor. Fabio and I originally thought of creating an immersive experience. We wanted to make a huge cloud, and we wanted the audience to be in this cloud, this nebula. But we realised that immersion was not the best way to experience the three-dimensionality of the nebula. We then tried to come up with a way to metaphorically trap the explosion of the supernova and observe it from the outside, as a laboratory experiment. Actually *Supernova (Cassiopeia A)* is part of a larger research project. I'd like to adapt the project for the theatre, Félicie d'Estienne d'Orves, *Supernova (Cassiopeia A)*, installation, realised in collaboration with Fabio Acero (astrophysicist), music by Laurent Dailleau, produced by Arcadi and Maison des Arts de Créteil, 2012, *The Dark Universe* exhibition, NASA – New Art Space Amsterdam, Sonic Acts, 2013.





in collaboration with a composer who writes a piece of music on the theme of supernova. It should be an abstract show with a smoke nebula transforming on the stage.

AA What is the larger research project about?

FEO I like to make series of works on the same theme. Both *Supernova (Cassiopeia A)* and my work *Eclipse* are part of *Cosmos*, a series of works in which I take natural events as my inspiration. I translate natural events into very intimate visual experiences. The works in this series are quite abstract and usually consist of shapes of light. With light there is a direct connection to science, because a lot of the scientific experiments in physics and astrophysics measure wavelengths. The visualisations that come out of measured wavelengths are like Photoshop picture layers. We don't always see what is real in the pictures because we don't see how many layers of interpretations and translation are present. But my works are primarily about perception and intimate experience. *Supernova (Cassiopeia A)* is not very realistic and should not be mistaken for a scientific visualisation. Instead I try to create a spatial experience. That is also why I always try to find a link between sound and light and try to provoke synaesthesia effects for the audience. While watching the piece people see things that spring from their own minds, and some feel this as an intimate, interior experience.

AA Can you explain how the piece functions technically?

FEO *Supernova (Cassiopeia A)* is in a way very simple and lo-tech. Smoke and fog are diffused in a transparent plexiglass box that stands on a metal base. The smoke appears and disappears. I project a video from the back onto the smoke. The spectator sees a 3D image because the video beam is diffused on the smoke. In reality the supernova remnant is a faded nebula. I cannot really present it like that, so instead I made a smokescreen, trapped in a plexiglass box. There are five fans in the box, run by a computer program, that make the smoke move in certain ways inside the box. There is also a soundtrack by Laurent Dailleau. We composed the piece together – we discussed how I was composing the light, and he the sound, and how the sound could bring the nebula to life. The piece lasts about fifteen minutes, and then it loops. I like to work with musicians who engage with the piece in a serious way, and who bring something to its development. I spent time with Fabio and Laurent during a residence at Maison des Arts de Créteil, working together on the theme and the realisation of this piece.

AA What are the video images that you project on the smoke?

FEO They are based on scientific images of Cassiopeia A. When we began the project the first 3D images of supernovae remnants had just been made. I took my inspiration from the scientific images, and graphically interpreted them. If you really know supernovae, you might be able to see that I used images of Cassiopeia A and not another supernova remnant, but it's really difficult to recognise. As I said, the scientific images are already abstract representations. We see a supernova as white, not as a colourful cloud. The explosion emits lights in all wavelengths from radio to gamma rays, but because our eyes are only sensitive to optical wavelengths, we see it as white. I kept the colours because they indicate that there are different types of matter in the exploded supernova.

AA The work is not entirely abstract...

FEO There is definitely a narrative element. It's the story of a supernova exploding and what happens after that.

There are different steps in the narrative. First there is the end of the life of a star. The star is pulsing. Then you have a figurative explosion, which is absolutely not what happens in reality. In reality it happens so fast that we cannot see it. After the explosion you have an expansion of many colours, which represent the different materials that make up the supernova nebula. That's the stardust that makes up the Earth, other planets, and life itself. At the end of that cycle all the different colours merge into a regular circle of white light.

AA Is it in any way close to how popular science visualises and explains these processes?

FEO *Supernova (Cassiopeia A)* could definitely not be exhibited in a scientific exhibition. It isn't close enough to reality. The piece has sound as well, and there is no sound in space. I used the sound so the audience can experience the work more physically. Although I'm not creating true scientific visualisations I did ask Fabio if he could find me the most current information on supernovae, because our knowledge of them is increasing fast. For instance, we wanted the real-time positioning of the different elements of the supernova explosion, but he told me that wasn't possible. Science doesn't know it precisely enough. But when we know it, we will use it. I would have loved to make a real-time supernova, but then the piece would maybe have a duration of ten years instead of fifteen minutes, and everything would be moving very, very slowly, and you would only see a difference if you observed it over a year. It all happens on such a different time scale than the one in which we live. That is very difficult to grasp.

AA You just said that you want to create spatial experiences with your work...

FEO What interests me in my pieces is creating an experience for the body, so that each spectator has a different perceptual experience, and maybe gains new knowledge of his perceptions and his own body. That's the basis of my work. That's why I work with space, with sculpture in space, and why I create interactions in space. The way spectators physically react to my pieces is central to my installations. My work is about time, sensation, and changing perception – leading to yet further questions.

DARK ENERGY, DARK MATTER, BIG DATA, INTIMATE DATA

Roger F. Malina

The era of big data started early for astronomy. But what we’ve learned from these vast amounts of data is that we are apparently ignorant of a large part of the Universe. Roger Malina shows the importance of Big Data, and how Big Data connects art and science.

Astronomy, with the agricultural and health sciences, is no doubt one of the oldest human sciences. The regularity of events in the sky, the daily and annual cycles, provided a predictable framework in a world that was often chaotic for early hominids. Humans lived at the mercy of climactic variations and disasters, threats from predators and unpredictable diseases and events. Astronomy on the other hand provided a metronome for human existence. And unusual events in the sky took on symbolic and religions importance. For most of human history astronomy has been a 'regalian' science associated with the ruling classes. Its role in navigation, even to the present, and with the contributions by the space sciences to GPS systems, provided a continuous link between science and economic benefit. Today China and India use the space sciences not only to demonstrate their technological prowess, but because we need the space sciences to help 'manage' our impact and activities on the planet.

Cosmology

Within astronomy, cosmology has had a particularly important role as it has contextualised our relationship to the larger universe. The Galilean revolution was at its root cultural. It is no accident that the theories of gravity have played such an important role in the development of modern science. The Universe provides one of our richest laboratories, testing and extending our knowledge of the world around us. Our understanding of the expansion of the universe from a hot dense phase, the Big Bang, has provided an overall 'calendar' within which stars, planets, and then life has emerged. The theory of evolution is joined at the hip with the theory of the Big Bang; astronomers played an important role in establishing the time scales of geological history; the cultural impact of astronomy is still felt in the debates with fundamentalist religions. Cosmology today is one of the most active areas of astronomy. New generations of space- and ground-based telescopes are producing a data flood of the nature and distribution of matter on all scales and distances going back to the first formation of stars in the universe after the Big Bang.

The dark universe

It is therefore ironic that astronomy is undergoing such a crisis of epistemology lately. The oldest science finds itself among the youngest sciences, with established understandings unsettled by new data. A recent issue of *Science Magazine* detailed ten fundamental areas of ignorance in modern astronomy that include:

- What is Dark Energy: 95% of the content of the universe is of an unknown nature except that it is causing the expansion of the universe to expand.

– What is Dark Matter: 83% of the physical matter in the universe is of an unknown nature except that it holds together galaxies and other large structures in the universe.
– Where is the Missing Matter: Of the matter that we can see or detect, 50% is still unaccounted for.

The article goes on to detail other major areas of ignorance such as the source of the most energetic cosmic rays in the universe, or how stars explode.[1]

In 2011 Saul Perlmutter, Adam Riess and Brian Schmidt were awarded a Nobel Prize in Physics for the discovery of dark energy. This Nobel Prize is perhaps ironic because it was awarded for discovering our ignorance of the nature of 95% of the universe. The story of this discovery is almost an exemplar of how good science is done, with small groups of scientists taking data, discovering step by step that the current understanding was very flawed and slowly convincing their colleagues who initially dismissed their work. As their work proceeded, it motivated the invention of new instruments and new telescopes that could capture the data needed to confirm or refute their ideas. New generations of space telescopes now on the drawing boards will collect vast amounts of data and perhaps elucidate the nature of dark energy.

Big data

The era of big data started early in astronomy. When I started my career in 1979 we were still using photographic plates. Then astronomers digitised their photographic plates. Then diode arrays and eventually Charge Coupled Devices (as used in cellphone cameras) started generating ever-larger volumes of data. Then it was discovered that these flows of data could not be combined; each field in astronomy used different data formats, different software systems, different archiving mechanisms. The astronomical community, supported by funding agencies, mobilised to develop data and software standards. With today's online virtual observatory databases scientists, or citizen scientists, can access large data sets from multiple telescopes. In a very real sense most of the telescopes are now networked into a large collective observing machine. New professions of data analysts have emerged and indeed many astronomers today have never used a telescope or recorded their own data; they use the data archives to make new discoveries. This evolution to the big data era spread rapidly to other

1. 'Mysteries of Astronomy', in *Science Magazine*, June 2012. www.sciencemag.org/site/special/astro2012/index.xhtm

fields of science, such as genomics, and now to business, government and the social media industries.

As many have pointed out, big data is not just more data. Science historian Daniel Boorstin called this an 'epistemological inversion'. What he meant was that the way that science could be done was changing. When Charles Darwin travelled to the Galápagos he was in search of new data. Data were rare; indeed all of Charles Darwin's data that transformed our understanding of human nature is contained in a series of notebooks on a bookshelf in his study. When data becomes plentiful, it changes the way most scientists do their work. They can study archives instead of studying the world. The way that governments fund science encourages the building of new instruments to record new data. The result is that the direction of science – which questions are investigated – and the methodology of science itself changes. There is often little funding to actually analyse and draw conclusions from the data.

Citizen science and data rights

In the information economy, 'data is power'. The opening of astronomical databases to the public has led to a large growth of citizen science with private citizens able to make scientific discoveries. This citizen science movement goes beyond the concept of the 'amateur'. In many fields citizen scientists are not only analysing online data; they are also generating new data. The social and political ramifications are important, as is being shown by the community mapping and community 'remote sensing' movements. With kites and balloons and remotely controlled drones, and of course cellphones, private citizens can collect and use data to contest the claims of governments or companies. The issue here is not big data but the right data and the right to data.

Several years ago I wrote an Open Observatory Manifesto asserting two new simple rights.[2] I first asserted that all citizens had a right to access data compiled with taxpayers' money. In astronomy this is actually implemented in most government grants; the astronomers are required to make their data public after a certain period. It is hotly contested in many other areas where governments refuse to make data, paid for by taxpayers, available to the public. The second assertion I made was that citizens had a duty to capture data and contribute it to the data commons. In fact, this is rapidly happening as social media systems archive all kinds of data uploaded by private citizens. We are rapidly becoming a data-taking culture. The biomedical sciences are being

2. Roger F. Malina, 'An Open Observatory Manifesto', in *Leonardo Electronic Almanac*, January 2010. http://www.leoalmanac.org/an-open-observatory-manifesto-by-roger-malina/

transformed as the cellphone becomes the generic data-taking interface. Data privacy has become a major ethical and societal issue.

Data visualisation and sonification

When you have very little data you can look at all of it. Astronomers used to study each galaxy in an image. When you start having millions or billions of objects in your database it is humanly impossible to do this. You start by automating the process but inevitably this means you build in blind spots. Every data-processing algorithm filters, sorts, selects and often throws away most of the data.

In astronomy one of the popular stories is how astronomers made surprising astronomical discoveries in data collected by the US military. The military satellites were watching for nuclear bomb tests during the Cold War era. The data analysis system rejected any signals that seemed to come from above the satellites, because they were looking for tests carried out underground or in the Earth's atmosphere. The astronomers discovered that the signals coming from above the satellite were real and were a previously unknown phenomenon now known to be emitted by gamma ray stars and galaxies.

As data volumes grow, traditional scientific illustration techniques become inadequate and this has led to the growth of new professions and techniques in data visualisation. Data can be displayed in three-dimensional immersive environments, in ways that are interactive and malleable. Techniques in complex network science allow the structure of the data to be analysed, drawing conclusions about the content of the data. Infoviz, bioviz and dataviz conferences are proliferating.

More recently scientists have started sonifying their data as well as visualising it. Human perception functions differently in visual and aural domains, different kinds of patterns can be detected and time evolutions noted. Sonification goes beyond alarms and alerts to systems of complex data representation exploiting the 3D and time-based nature of sound. Composers and sound artists, such as Scot Gresham Lancaster, have been on the forefront of developing these techniques.

No data or the wrong data

What if there is no data or if we are collecting the wrong data? Dark energy astronomers are collecting vast amounts of data but since we don't have good theoretical models, other astronomers have pointed out that the data might be useless. Without good hypotheses to test it, how do we know which data is relevant? The observational astronomers reply that dark energy was discovered without a guiding theory, and that many discoveries are not driven by the process of confirming or falsifying hypotheses. Science indeed advances by both approaches. During the birth of the big data transformation some argued that it was ‘the end of theory’. Just collect data, look for correlations and do extrapolations. In many cases this may work very well, but in others understanding causal networks is necessary to interpret correlations and extrapolations. There is a very real danger that the data flood will blind us to the fact that we don’t have the most relevant data. And it’s easier now to get funding to analyse big data than to fund research where you don’t yet know which data you need.

Quantitative data and qualitative data

One of the ancient battlegrounds between the sciences and humanities has been whether scientific understanding can only come from quantitative data. The social sciences and the cognitive sciences find themselves straddling the digital divide. Within the arts, the digital and new media arts are still fighting fundamental battles with art forms that don’t rely on manipulating digitally encoded, quantified data. In recent years the birth of the Digital Humanities has re-awakened these disputes as the new generation of humanities scholars, born digital, develop new research strategies that are more easily funded today than pre-digital scholarship. Big Data is re-orienting the humanities, driving curiosity towards questions that could not been tackled before, but also putting in the shade fundamental questions that have no data or rely on unquantifiable qualitative analyses.

Intimate data

For artists perhaps the question is elsewhere; the human experience with an artwork relies on qualia of human cognition. That experience is in a sense neutral to the technology used to develop the artwork. Artists have often been early adopters of new technologies, and in many cases have made inventions for their art-making that have been widely used. Metallurgy and chemistry have long straddled the fine and applied arts. We now know that the human senses are very efficient filters, and that almost all of the world around us cannot be directly perceived by human senses. Most of the universe is dark. That artists use data obtained by scientific instruments seems to be a desirable process of cultural appropriation of phenomenon to bring them into the intimacy of personal perception and cognition. In his books like *The New Landscape in Art and Science* (1956), György Kepes asserted the right of artists to use scientific data as a raw material like any other. In a sense the citizen science movement has its equivalent in ‘citizen’ art, with artists also generating new data using scientific instruments for their own purposes, I believe this should be encouraged. There is a growing movement to find new ways to cross-link Science and Engineering to the Arts and Humanities. The Dark Universe and Big Data are common ground to be explored.

A SINGLE SKY: LEARNING TO SEE THE HEAVENS THROUGH RADIO

David P.D. Munns

Humanity now sees the universe with far more than merely its eyes. The last half-century has exploded the once comfortable notion of astronomy as a science centred on seeing. Since the invention of radio, we now listen to the Universe, and rockets transport telescopes and detectors into space itself to receive all the information the heavens throw at us, from gamma to radio waves. Munns' essay, based on his book *A Single Sky: How an International Community Forged the Science of Radio Astronomy* takes us to one of the pivotal moments in history when we learned to see the stars and galaxies through radio.

For more than 3000 years, astronomers have used light visible to the naked eye to study the working of the heavens. The ancient watchers of Stonehenge aligned their monument with the visible solstices; Claudius Ptolemy, the famed Roman astronomer of the second century AD, successfully found mathematical models based on a long lineage of Babylonian observations to predict the motions of the heavens. Over a millennia later, Renaissance astronomer Nicolaus Copernicus, who sought to reform Ptolemy's astronomy, was himself a keen observer. His new heliocentric hypothesis, proposing that the Earth revolved around the Sun, seems to have owed much to observations of the changing brightness of planets. Tycho Brahe may have made as many as ten thousand observations of the heavens, but it was a mathematician and philosopher by the name of Galileo who made some of the most important observations of all, for Galileo looked at the heaven through a new invention, the telescope. Witnessing such novelties as craters on the Moon, satellites orbiting Jupiter, and seemingly innumerable stars, the telescope revealed not only the flaws of the Aristotelian earth-centred idea of the universe but also the limitations of the human eye as an instrument to observe nature. For the next five centuries, telescopes grew in size and expense, all seeing more and more, first nebula, then spectral lines, and, by the 1930s, even other galaxies.

No less dramatically than the optical telescope, the radio telescope once again shattered humanity's vision of the heavens. In just over the last half century, seeing through radio has fundamentally altered how astronomers see what they see, and altered our very conception of the universe we live in. The new radio telescopes of the 1940s and 1950s exposed vast swathes of the celestial heavens to investigation and permitted the new radio astronomers to peer through dust clouds and gases. Harnessing radio waves from the Sun and stars, the evidence of the science of astronomy was no longer constrained solely to visible light. Suddenly astronomers had access to another large segment of the electromagnetic spectrum, at radio wavelengths to complement the visible wavelengths. Because radio waves penetrate the atmosphere, as does visible light, radio astronomy didn't have to wait for reliable rockets to launch detectors into space.

What was the technology of radio, and how was it to be applied to astronomy? The possibilities seemed endless, like so many other technologies in the 1950s. For example, in 1956, the Harvard physicist Edward Purcell, already a Nobel laureate, speculated that the radio telescope of the future 'may… want a small cryogenic laboratory mounted out there on the end of it'. He asked whether the new technology of radio, not to mention rockets, electronics, and nuclear physics, had rendered the traditional optical telescope obsolete. The technological reshaping of astronomy after 1945 ultimately turned on what the word 'astronomy' meant to those who called themselves astronomers. Purcell asked pointedly why radio astronomers built observatories and not laboratories, why they now used telescopes and not antennas, and why they didn't simply call themselves physicists?

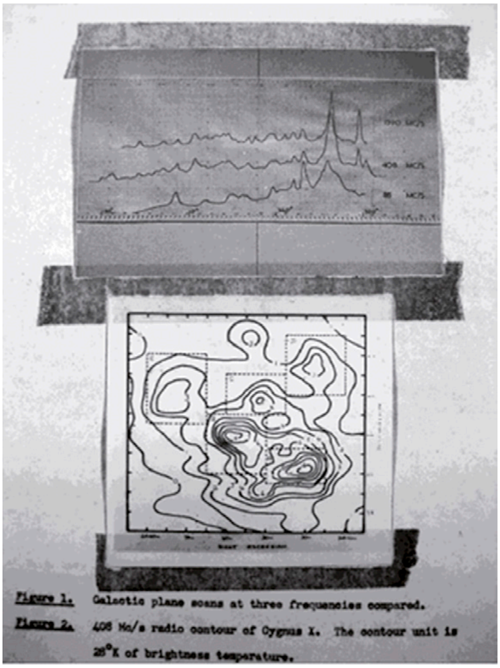
It is revealing of the entire nature of science that astronomy, one of the longest-studied and most coherent bodies of knowledge, had, before radio astronomy, been limited to half an order of magnitude of the electromagnetic spectrum – the visual range (approximately 450–800 nanometres). Trying to discover evidence of the shape of the galaxy or the laws of the universe under such limitations might be comparable to reading only one paragraph in the middle of a newspaper page, perhaps less, and expecting to know the day's news. Now, after more than 50 years of radio astronomy, knowledge of the size and the structure of the cosmos expanded as the vision widened. Radio astronomy was, in fact, the first of a whole set of new astronomies. Modern astronomers now 'see' not only in the radio range (approximately 1 millimetre–50 metres) but also in the X-ray range (approximately 0.004–10 nanometres), in the ultraviolet range (approximately 0.1 micrometre–350 nanometres), and in the infrared range (approximately 0.71000 micrometres). To paraphrase a noted writer of science fiction, it is not that the universe is more astonishing than we can imagine; it is that it is more astonishing than we can see with only our eyes.

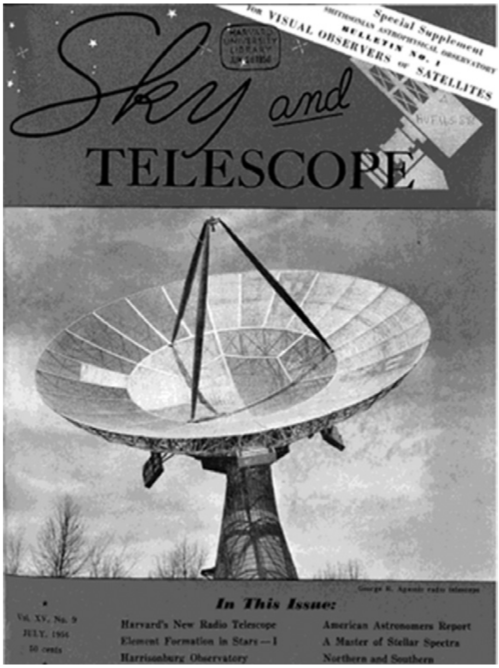
In the years after 1945 radio techniques and radio equipment presented profound challenges to optical astronomers, who found early radio observations difficult to integrate into their scientific work, just as in the sixteenth century naked-eye astronomers had found it difficult to master the telescope. (Famously, Galileo had to explain to one prince that the telescope did not function properly because the prince was looking out of his window in the middle of the day during a snowstorm). Traditional astronomers, now suddenly revealed to have been constrained to the optical range, wondered how they could make use of radio telescopes and 'super-heterodyne receivers', or how they might read the information generated on chart recorders. Radio didn't merely extend sight; it became an entirely different sense of vision.

Much of the formation of the community is nicely encapsulated in the struggles of optical astronomers and radio physicists to incorporate photographic plates and visual spectra with radiographs. The overlapping pictures looked more like weather forecasts than star fields. Moreover, a new sense of community became necessary between scientists of many stripes, because radio supplied information about the heavens that had to be translated into the language of the astronomers.

left – The new radio vision of the heavens. Above: A chart showing radio intensities at three wavelengths (1390, 408 and 85 megacycles per second) from the galactic plane between 10º and 340º. Below: A radio map of Cygnus X, the contours showing the change in radio intensities across the object.

right – Harvard University's 60-foot radio telescope. Cover of *Sky and Telescope*, July 1956.





A community of researchers

A new vision and a new astronomical community formed the foundations for the giant radio telescopes of the 1960s in Australia, Britain, the Netherlands, the Soviet Union, and the United States. Through them sight was extended once more, and the radio astronomers would reveal the spiral structure of our own galaxy, discover an entirely unexpected and strange class of ultra-intense objects called quasars, and measure the universe's residual background temperature of 3 degrees Kelvin. Radio astronomy would change our ideas of how the universe looked, how we learned about it, and even our idea of how old it was. It would provide evidence for the great cosmological debates between the 'steady state' and the 'Big Bang'. And in July 1969 radio telescopes around the world would receive the television images of the first moonwalk and re-transmit them to the world.

There was a historical process of learning to see by means of radio waves. The radio astronomers believed that, to succeed, radio physicists and their radio receivers would have to join with optical astronomers and their optical telescopes. The new radio astronomers understood science as an open, inclusive, international, interdisciplinary process. In 1954, for example, the Australian radio astronomer Joseph Lade Pawsey, speaking as president of the International Astronomical Union Commission, said, 'Radio astronomy, if it is to develop properly, must depend on a blending of radio invention and astronomical insight'. To see the full heavens via visible waves and radio waves, astronomy as a field would have to 'blend' optical insight and electronic invention. But it would also have to blend an Australian radio physicist, which Pawsey was, with established optical astronomers, at whose meeting he was presiding. The 'blending' of optical and radio into a single astronomy required a community style of science – a style considered entirely 'proper'.

To learn to see the heavens via radio, earth-bound radio astronomers would require a culture of interdisciplinary and international integration and cooperation. An emphasis on cooperative community opposes the renowned view of the philosopher of science, Thomas Kuhn, who argued that 'competition between segments of the scientific community is the only historical process that ever actually results in the rejection of one previously accepted theory or in the adoption of another'.[1] In the case of the emergence of radio astronomy as a science, an emphasis on competition among schools, nations, theories, or even

1. Thomas S. Kuhn, *The Structure of Scientific Revolutions*, Chicago: University of Chicago Press, 1996 (1962) p. 8.

technologies would incorrectly characterise an altogether cooperative process of community building. I argue for the concept of community in recent science. Instead of a fractious world of science, the radio astronomers saw a single sky, unifying disciplines as well as nations.

There were other new sciences that emerged during the Cold War, including cybernetics, quantum chemistry, and, of course, molecular biology. Radio astronomy had many things in common with them all, but because radio physicists learnt to see the heavens through radio eyes, radio astronomy transcended many of the earthly limitations of those other sciences. While, for example, molecular biologists fiercely competed with one another to be the first to discover the structure of DNA and then its methods of replication, in astronomy, the blending of visual and radio wavelengths paralleled the social inclusion of all scientists into a single science of astronomy. After a generation of this open, cooperative style of science, astronomy not only 'saw' the heavens via much of the electromagnetic spectrum, but also actively included every astronomer.

Perhaps the obvious moment was when in 1973, the Soviet astronomer, V.A. Ambartsumian, expressed the belief that 'contemporary astronomy has come close to becoming all-wave astronomy'. Ambartsumian's comment was made at a conference on communicating with extraterrestrial intelligence at which all-wavelength astronomers sought not only to establish contact with extraterrestrials but also to solve the problems of 'communication [among] nations'. In other words, working on extraterrestrial communication would help astronomers to deal with one of the fundamental barriers of the Cold War world: the Iron Curtain. If astronomers could figure out how to talk to extraterrestrials, they could figure out how Americans might talk with Russians, and vice versa.

1945–1949 – radio astronomy in Manchester

One good story of how astronomers learnt to see via radio comes from one of the earliest recognisable groups of radio astronomers under Bernard Lovell outside Manchester in the United Kingdom. Very soon after the end of World War Two, Lovell moved some old radar trucks into the middle of a muddy field called Jodrell Bank outside Manchester and tried to detect cosmic ray showers. This initial research effort did not concentrate on anything that could be termed radio astronomy. Lovell was a high-energy physicist before the war, and was keen on resuming his old work. He thought of applying the sensitive radio receivers developed for radar in Britain to the problem of detecting cosmic rays, high-energy bursts coming from space through the atmosphere. While we now know that his proposed programme was deeply flawed, at the time they appeared to be profitable lines of research. Cosmic ray research utilised his wartime expertise, and it was of immediate interest in the wake of the

The Atacama Large Millimeter/submillimeter Array (ALMA) is the largest astronomical project in existence. When finished, ALMA will be a single telescope consisting of 66 high-precision antennas 5000 metres above sea level on the Chajnantor plateau in northern Chile.

top – ALMA under a night sky.

bottom – The ALMA correlator, one of the most powerful supercomputers in the world with over 134 million processors, performing up to seventeen quadrillion operations per second.

The Horn-reflector antenna at Bell Telephone Laboratories in Holmdel, New Jersey, was built in 1959 for pioneering work in communication satellites for the NASA ECHO I.

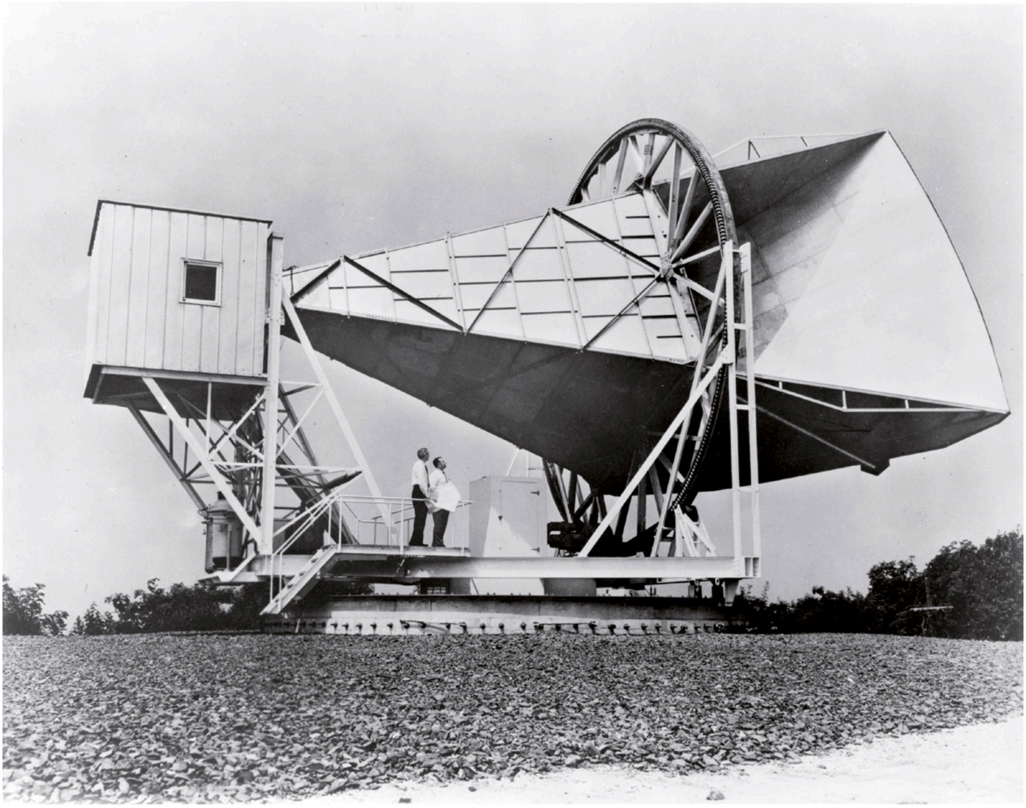
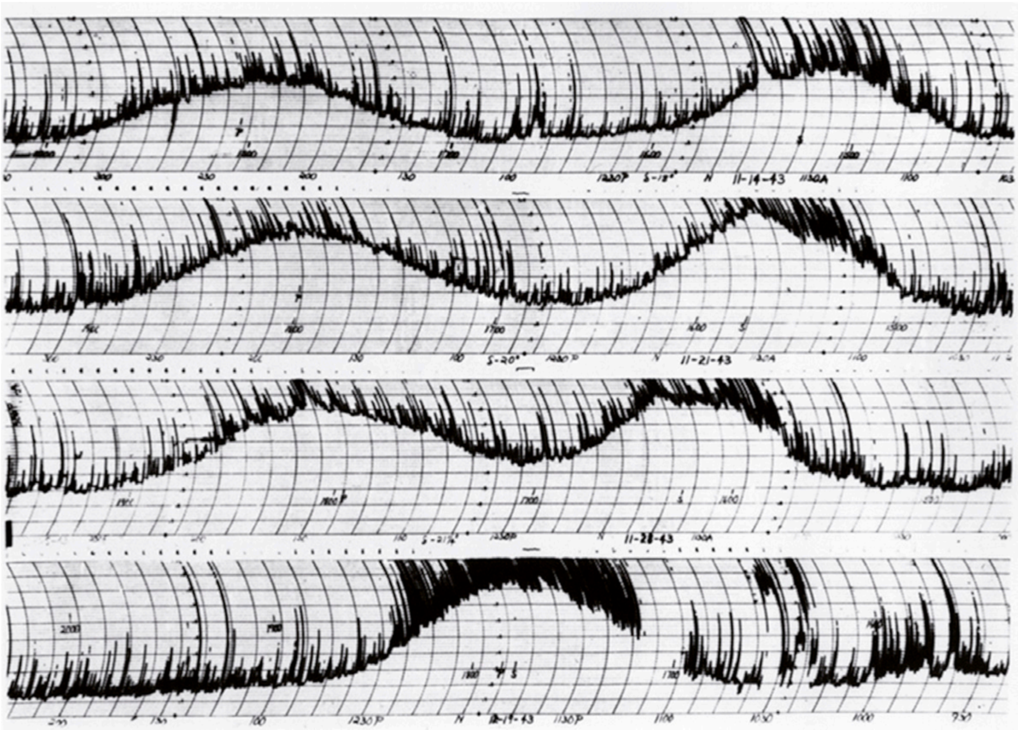


Chart recordings made in 1943 from Grote Reber's experimental radio telescope. The spikes or 'fuzz' are due to interference from automobile engine sparks. The broader peaks are caused by the Milky Way and the Sun.



Arecibo Observatory in Puerto Rico is the world's largest single-dish radio telescope. Completed in 1963, the observatory is used for research in radio astronomy, planetary radar, and terrestrial aeronomy.

nuclear research that had produced the atomic bomb. To detect cosmic rays Lovell took advantage of piles of leftover wartime radar sets, mostly imported from the United States in the last days of the war, and quickly outdated by newer models, some not even out of their wrappings before being discarded – quite a metaphor for the next half-century of American materialism. Lovell was experienced in antenna design, circuit noise, and early solid-state electronics; he was accustomed to looking at radio noise as a display on screens or printed out on chart recorders.

Lovell first began recording sightings of what he believed were reflections from the ionised trails of cosmic ray showers toward the end of 1945. Lovell's wartime colleague J.S. Hey and his old mentor Patrick Blackett, both also working with old radar equipment, disagreed. They both thought that Lovell had witnessed radar echoes from meteors. Lovell's mentor turned out to be right – most of the events were indeed meteor showers. Undeterred and flexible, Lovell countered that meteors might be of interest to optical astronomers, noting happily that few astronomical texts paid them much attention and that professional astronomers paid them even less. A novel technique combined with an under-explored area of an established discipline deserved investment. But, requiring traditional astronomical knowledge, Lovell began a cooperative arrangement with an amateur meteor astronomer named Manning Prentice, a solicitor by trade. Prentice, presumably enamoured by Lovell's novel method of meteor detection, introduced the radio physicist to amateur observational astronomy during the 1946 Perseid meteor showers.

A year after the greatest war ever fought, Lovell and Prentice lay on deck chairs in a field at Jodrell Bank measuring meteor trails and estimating magnitudes of each event. The scene, celebrated by Lovell in his memoirs, sounds like a couple of retired astronomers engaging in their hobby. The relaxed vista seems particularly incongruous against Lovell's later self-portrait as being intensely driven toward securing his place in radio astronomy (especially via the giant 250-foot Jodrell Bank radio telescope that was completed in 1957). In fact, the apparent serenity elides the strenuous efforts Lovell was already making to attract astronomers to his work.

Initially, Lovell anxiously tried several tacks to ingratiate himself with astronomers, including weighing in on a debate about the size of particles that existed permanently in interstellar space. A few professional astronomers, having made crude estimates, hoped that radar could accurately measure the velocities of sporadic meteors, and perhaps even their incident angle, to judge whether meteors possessed enough velocity to orbit the Sun. Lovell and Prentice presented professional astronomers with their observational and radio work later that year and pointedly published in the *Monthly Notices of the Royal Astronomical Society*. Meteors took up nearly three years of work at Jodrell Bank, after which it would be concluded that most sporadic meteors do in fact orbit the Sun. The real importance of the work was that through meteor research and talks at the Royal Astronomical Society, Lovell and Jodrell Bank became 'part of the astronomical community'. The Fellows of the Society, Lovell later said, 'began to grasp that [radar] was a new astronomical technique'.

Lovell's claim to be part of a new community remains among the earliest moments in the creation of a renewed communal ethos in science towards open exchange and cooperation, and a resistance to military work or compartmentalisation characteristic of modern astronomy. Science isn't only about what scientists work on, it is also often about what they do not work on. Lovell reached outside high-energy physics to the British astronomical community to gain social credit for his work on meteors. Lovell, like the vast majority of radio astronomers, explicitly avoided any continuing work on air-interception radar or improving bombing accuracy, work that had made him quite famous during the war. Instead, by 1949, Lovell was studying meteors with nothing more than some old radar sets, a camera, and a few deck chairs.

Another advance in the formation of the radio astronomy community took place at around the same time. It was a key moment in the radical change in our vision of the heavens. Around 1949 Lovell had a graduate student begin building a large parabolic dish. The dish, made entirely of wire strung from scaffolding tubes, eventually reached a diameter of 218 feet and a depth of 24 feet. It was termed the 'transit telescope' because the Earth's motion effectively caused the heavens to transit across the beam. At that size, the dish was an order of magnitude larger than any other antenna then in existence. Lovell's planned cosmic ray experiments necessitated a substantial increase in receiver sensitivity, which dictated the instrument's size. The dish offered the added simplicity of having only one dipole antenna system at the focus as opposed to a broadside array in which a large number of dipoles and connections would have to be altered each time researchers wanted to change wavelengths. Lovell later reasoned that this simplicity outweighed the difficulty of constructing a wire parabola.

A major hurdle appeared at once. Armed with more sensitive receivers, Lovell disconcertedly learned (from yet another graduate student, Victor Hughes) that the limit of noise for the telescope pointing at the sky was now set by the unexplained phenomenon of 'cosmic noise' that Karl Jansky had happened upon in the 1930s and that John Bolton in Australia was attempting to isolate to a particular astronomical object. And so, soon after his arrival, Robert Hanbury Brown turned the transit telescope toward the problem of cosmic noise and abandoned Lovell's plan for research into cosmic rays. Hanbury Brown came to Jodrell Bank as a Ph.D. student, and possessed all the confidence of youth. Hanbury Brown readily admitted – indeed fondly recalled – that he 'didn't know any astronomy' but 'reckoned that it would be easy to learn enough as I went along'. Lovell remembered Hanbury Brown as a fellow radar 'boffin' from the war days. As near contemporaries, Hanbury Brown and Lovell shared parallel careers within the British wartime scientific establishment as 'boffins', a charming English term denoting inventive skill drawn from tacit knowledge and some pluck.

The transit telescope took Hanbury Brown nearly a year to bring to full operation. Given the directional confines of the instrument (initially limited to a single declination, 53° N), he concentrated first on the Andromeda nebula, taking 90 days in mid-1950 to produce a map of the nebula measuring 1 hour by 6 degrees. It took Hanbury Brown's considerable talents to learn how to adjust the central 126-foot mast of the telescope so it could scan other parts of the sky. 'To avoid kinking the mast', he later recalled, 'we had to tilt it in almost imperceptible stages and on a good day, when it wasn't raining or snowing, it took us about two hours running from guy to guy shouting at each other and peering though theodolites, to move the beam through one-beam-width (2 degrees)'. Here is a classic 'boffin' image of a young researcher struggling to make equipment work in the face of that very English adversary, the weather. Yet he was also struggling to utilise and define a new type of instrument, one that had familiar components but distinctly unfamiliar purposes. He wanted to scan more of the sky, but why he might want to do so, or what he might find there, remained a mystery. Of course, the image of running around a muddy field became romanticised in his memory. After leading a large astronomical facility in Australia in later life, he reminisced: 'When nowadays I see people in nice warm control rooms drinking coffee and swinging the beams of their telescopes about the sky by simply pushing buttons, I think of the hours and hours we spent steering the beam of that telescope'.

What Hanbury Brown did know in 1950 was how much effort it took to point his instrument at other parts of the sky. Here is also another important theme about learning to see via the new vision of radio: it, in effect, turned all astronomers back into students – they had to re-learn what they had learnt. As students, the new radio astronomers struggled with their instruments in the same way they struggled to be understood as part of the broader astronomical community. In the two decades after 1945 they ran from wire to wire, fiddling, tinkering, fixing, and hoping; a generation later, these students controlled a radio astronomy community spanning half a dozen countries, commanding a dozen major instruments, and uniting at least three disciplines: astronomy, radio physics, and electrical engineering.

In short, it took a generation for the disciples to become masters. It was similar to the generation of students that had learned the new mathematical physics at Cambridge in the nineteenth century. As Andrew Warwick described in his masterful *Masters of Theory*[2], the spread of General Relativity in the 1920s, like that of Maxwell's electromagnetic theory 50 years earlier, took place largely in the classrooms of Cambridge. Both in content and in style, pedagogy supplies much of the formulation, practice, and dissemination of science. Both James Clerk Maxwell and later Arthur Eddington relied on the intense undergraduate mathematical training regime at Cambridge to fully explore, explicate, and defend their novel conceptions of nature. The performance of the classroom acted out the defence of the theory. In their Senate House exams, however, the brightest students were expected to challenge their master's proofs and taught techniques, and even to generate novel results.

The new disciples of radio astronomy had to learn how to use radio telescopes, how to interpret what they saw, and how to communicate that to their now fellow optical astronomers. We can see that process of learning in Hanbury Brown's work at Jodrell Bank in the early 1950s. Hanbury Brown's map of the Andromeda galaxy began a broad survey project, which eventually charted 28 galaxies that looked normal when observed with optical telescopes. It attracted the interest of local Manchester astronomer Zdeňek Kopal who suggested that the supernova remnant of Tycho Brahe's new star of 1572 might prove to be a radio source. Hanbury Brown shared his radio surveys with Kopal; Kopal offered encouragement and potential direction based on his astronomical expertise. Thus, through cooperation and interdisciplinary exchange, Hanbury Brown and Kopal tackled one half of radio astronomy's main question of the 1950s: Were radio sources 'normal' astronomical objects, or were they exotic and perhaps extra-astronomical objects?

After trying to ingratiate himself with astronomers through his work on meteors (objects perhaps so normal as to be boring), Lovell eagerly embraced the attention his motley band of graduate students and instruments now attracted. Kopal, who in the 1950s visited Jodrell Bank every week to deliver lectures, tried to teach Lovell, Hanbury Brown, and their graduate students astronomy. In the background, Lovell's old mentor, Patrick Blackett charged Kopal with making the Jodrell Bank group 'astronomy-minded'.

2. Andrew Warwick, *Masters of Theory: Cambridge and the Rise of Mathematical Physics*, Chicago: University of Chicago Press, 2003.

1949 – Radio physics becomes radio astronomy

With the parabolic dish as the new instrument of radio astronomy, and some significant questions about the normalcy of radio stars emerging, and the cooperation of a local optical astronomer, the stage was set to learn how to see through radio. When astronomers learned to see via radio, the radio physicist became the radio astronomer and the radio antenna was transformed into the radio telescope. It all took place quite rapidly; in fact, after two weeks of preparation, those monumental changes occurred over the course of a weekend. If we consider the action slowly, we can see the monumental changes Lovell and Hanbury Brown brought to astronomy.

It was in July 1949 that some 60 Fellows of the Royal Astronomical Society travelled to Manchester for a two-day meeting and an informational tour of Jodrell Bank. It was only the second time the society had met outside London. Lovell proudly informed his Jodrell Bank colleagues that the honour couldn't be of 'greater significance to Jodrell Bank and to all of us individually'. Thus, they all 'must do their utmost' to ensure the success of the Royal Astronomical Society's visit. Radio work on astronomical topics had secured Jodrell Bank's practitioners their 'magnificent accommodation'. A response not 'worthy' of it could see it stripped ingloriously from them all, and all their efforts 'shameful[ly]' abandoned. 'Search out' your 'best photographs or results', Lovell instructed, 'and get them reproduced or platted on a grand scale'. Impression and image were most important. Lovell ordered charts and data turned into pictures. 'Remember our visitors will be experts in astronomy, but will probably not know much about radio.... Prepare what you are going to say accordingly – simple explanation of technique, but not of meteors or sunspots!' This was the moment radio physics became radio astronomy. The Royal Astronomical Society came to Lovell, but Lovell made sure that his visitors recognised that photographs took precedence over mere data. Lovell and the Society merged the social and intellectual strands of a scientific community. Jodrell Bank combined radio techniques with familiar astronomical presentations and gave priority to astronomical relevance.

Retracing Lovell's careful preparations, we can witness the process by which the vision of a science changes. Lovell insisted that the entire weekend be a spectacular performance. 'Many visitors complain that our showmanship is abysmal. Few of you can tell a good straightforward story of what you are doing, or readily show convincing results without searching through acres of paper or miles of film'. The sociologist of science Bruno Latour once argued that the popular understanding of science was as 'a body of practices widely regarded by outsiders as well organised, logical, and coherent'. 'In fact', Latour observed, science ‘consists of a disordered array of observations with which scientists struggle to produce order’.[3] Lovell and his graduate students imposed an order on the disordered mess of radio charts and data, building a picture of the radio astronomy instrument as well as the radio astronomer for their astronomical audience. The Jodrell Bank group’s performance ordered radio astronomy within the body of astronomical knowledge.

That work fell, once more, largely to the graduate students. Ellyett and Greenhow collaged the meteor velocity photographs. Moran and Gatenby assembled diagrams of moon echoes including an ‘apparatus functioning’. Hughes and Little plotted Jodrell’s Cygnus runs and mentioned Cambridge’s results, while Clegg (as the only other staff member) and Closs handled the theoretical description of antennas. Lovell himself took on the formidable task of selling the ‘Large Jodrell Plan’. All papers had been read aloud two weeks before, and all photographs mounted and put on display a week before the official ‘target date’. Display, authority, and organisation governed Lovell’s quasi-militaristic planning for the Royal Astronomical Society’s Fellows. But in that organisational mode, the operation of the radio astronomy community at Jodrell Bank became clearly visible to outsiders, as clearly visible as radio astronomy knowledge became to the visiting astronomers by way of photographs. The graduate students generally handled instruments and data, while Lovell handled the synthetic overall picture and the broader plans.

After two days of wining and dining, lectures, discussions, tours, and big plans, Lovell unveiled before the Royal Astronomical Society his ambitious and wildly expensive plan for a giant radio telescope. Still, the astronomers didn’t fully know what to make of Lovell’s performance. At the last dinner, the Society’s president ‘congratulated the Jodrell Bank team on this new development in observational astronomy (or physics)’. The literal text of the speech betrayed optical astronomers’ continued uncertainty about the exact nature of Lovell’s programme. It may be the best description of early radio astronomy we have: ‘observational astronomy (or physics)’. Radio astronomy sat on the knife-edge, poised between the world of physics and the world of astronomy.

On one point, however, the Royal Astronomical Society was clear: ‘The high-spot of the meeting was undoubtedly the show you put on at Jodrell Bank’. The show was the first step in the long process whereby radio physics became radio astronomy. Like astronomers the world over, the Fellows accepted the importance of instrumental prowess to

3. Bruno Latour and Steve Woolgar, Laboratory *Life: The Construction of Scientific Facts*, Princeton N.J.: Princeton University Press, 1986.

scientific status and so enthusiastically listened to Lovell's long speeches and grandiose plans for a giant radio telescope in Britain. As Englishmen, they understood Britain's declining state; as members of a technocratic elite, they were impressed by technical innovations as an approach to solving scientific problems. To top it all, they witnessed a new team of disciples hard at work effectively transforming radio charts and data into comprehensible all-wave astronomy. That work continues to the present day. Radio astronomy's young boffins, now its retired masters, made its new pictures. But not all saw it as astronomy. Jack Ratcliffe at Cambridge, mentor to Lovell's great rival and eventual Nobel Prize winner, Martin Ryle, saw Lovell's work in a tradition of ionosphere physics; Lovell himself came to view radio physics as a technique of astronomy; the president of the Royal Astronomical Society genuinely didn't know what it was.

Indeed, the new radio vision of the heavens opened up once more the eternal question of what the study of the heavens is. What it was not was a science firmly yoked to the whims of the military-industrial complex, like so many during the Cold War. As early as 1944, Bernard Lovell, then working at Britain's Telecommunications Research Establishment on radar aids to guide heavy bombers to their targets, argued to his superiors that Britain must 'take [fifty people] away from this guarded enclosure and re-establish... the facility of thinking'. Similarly, as Australia's giant radio telescope sought increased funding in 1955, its guiding visionary, Edward Bowen, revealingly commented that 'even in research circles there has been a disappointing tendency to say that sheep are more important and that radio astronomy is all right for other countries'. And in the United States, Merle Tuve, pioneer in the use of pulsed radio waves and later head of the Department of Terrestrial Magnetism at the Carnegie Institution in Washington and of that institution's small radio astronomy effort, declared in the mid-1950s that radio astronomy was 'a study of the heavens not just glorified electronics'.

Radio astronomy became a 'poster child' for the resurgent notion of science for its own sake. In his 1954 presidential address to the British Association of the Advancement of Science, Sir Edward Appleton argued that post-war Britain placed too much emphasis on the 'applications of science in the practical life of our country'. Appleton presented a vision of science 'pursued for its own sake'; there was value in science's ability to 'enlarge men's horizons and invest the world with deeper significance'. Evoking the experience of Edmund Hillary and Tenzing Norgay on Mount Everest, Appleton implored the audience to support scientific work that seemed to have little practical purpose. He concluded with a singular example of the kind of pure scientific inquiry that should be supported for no practical purpose: 'The radio telescope has... shown itself to be an important adjunct to the world's greatest optical telescope'. Not only did the new working relationship between radio and optical telescopes forge the new community of radio astronomers, but it also symbolised scientists' expectations of turning wartime technology into a broader horizon for mankind.

Bibliographic Note

All of the sources for any quotations may be found in full in David P.D. Munns, *A Single Sky: How an International Community Forged the Science of Radio Astronomy* (Cambridge Mass.: MIT Press, 2013). The account of earlier radio pioneers first encountering the noisy heavens can be readily found in Woodruff T. Sullivan III, *Cosmic Noise: A History of Early Radio Astronomy* (Cambridge: Cambridge University Press, 2009), while the later expansion of telescopes is told in W. Patrick McCray, *Giant Telescopes: Astronomical Ambition and the Promise of Technology* (Cambridge Mass.: Harvard University Press, 2006). The larger agenda of communication among nations arises in *Communication with Extraterrestrial Intelligence* (CETI), ed. Carl Sagan (Cambridge Mass.: MIT Press, 1973, pp. 2–3). For the case I dwelt upon in this essay, Jodrell Bank, Bernard Lovell wrote several memoirs, for example, Sir Bernard Lovell, *The Story of Jodrell Bank* (New York: Harper & Row, 1968), which need to be read alongside the wealth of archival material preserved in the Jodrell Bank Archives at the John Rylands Library of the University of Manchester itself. Additionally, there is also a memoir from the local Manchester astronomer Zdeňek Kopal, *Of Stars and Men: Reminiscences of an Astronomer* (Bristol, Boston: Adam Hilger, 1986), which fills out the story. An older, more sociological account is David Edge & Michael Mulkay, *Astronomy Transformed: the Emergence of Radio Astronomy in Britain* (New York: Wiley, 1976). For the quip about 'glorified electronics', see the letter from Merle Tuve to the NSF Panel on Radio Astronomy of 2 May 1955 in the Merle Tuve Papers, at the Library of Congress, Washington D.C. Box 329, folder 'NSF Panel, Radio Astronomy, May–June 1955'. For accounts of the various guises of 'boffins', see firstly Ronald Clark, *The Rise of the Boffins* (London: Phoenix House, 1962), while Robert Hanbury Brown's, *Boffin: A Personal Story of the Early Days of Radar, Radio Astronomy and Quantum Optics* (Bristol, Boston: Adam Hilger, 1991) gives a detailed account directly relevant to my story here. The overall theme of seeing via radio owed much to the analysis of Galileo's own struggles to 'see' through his telescope, wonderfully told in the introduction to Eileen Reeves, *Painting the Heavens: Art and Science in the Age of Galileo* (Princeton N.J.: Princeton University Press, 1997). For the related issue of the struggle to master and learn new knowledge and science, see Andrew Warwick, *Masters of Theory: Cambridge and the Rise of Mathematical Physics* (Chicago: Chicago University Press, 2003). Any debate on competition and community in science must begin with Thomas S. Kuhn, *Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1996 (1962), whose conception of changing scientific paradigms continue to resonate strongly with scientists' own ideas about how knowledge progresses.

THE ORBITING GAZE

Bitcaves

After centuries of looking at space from the Earth, we are now in equal measure looking at ourselves *from* space, through space stations and orbiting satellites launched into the atmosphere. But who is looking, where do they look, and what do they see? What do we actually know about geopolitical space power? Before these carriers of our 'orbiting gaze' eventually turn into space debris, we explore in three sections the active satellites currently orbiting around the Earth. [1]

1 The data used in these sections is based on the UCS Satellite Database, version 12–1–12, a listing of 1000 operational satellites currently orbiting Earth. Information included in the database is publicly accessible and free, and was collected from corporate, scientific, government, military, non-governmental, and academic websites available to the public. Source: www.ucsusa.org/assets/documents/nwgs/UCS_Satellite_Database_officialname_12-1-12.txt.

	Current Official Name of Satellite	Operator/Owner	Country of Operator/Owner	Users (C - Commercial, G - Government, Civ - Civil, M - Military)	Purpose	Class of Orbit	Launch Mass (kg.)	Year
1	ABS-1	Asia Broadcast Satellite	International	C	Communications	GEO	2,894	1999
2	ABS-1A	Asia Broadcast Satellite	International	C	Communications	GEO	1,459	1996
3	ABS-7	Asia Broadcast Satellite	International	C	Communications	GEO	3,500	1999
4	AcrimSat	NASA	USA	G	Solar Physics	LEO	115	1999
5	USA 139	NRO	USA	M	Surveillance	GEO	4,500	1998
6	USA 171	NRO	USA	M	Surveillance	GEO	4,500	2003
7	USA 202	NRO	USA	M	Surveillance	GEO	5,000	2009
8	USA 223	NRO	USA	M	Surveillance	GEO	5,000	2010
9	USA 237	NRO	USA	M	Surveillance	GEO	5,000	2012
10	USA 214	US Air Force	USA	M	Communications	GEO	6,169	2010
11	USA 235	US Air Force	USA	M	Communications	GEO	6,169	2012
12	Aeneas	Dep. of Homeland Security	USA	G	Technology	LEO	3	2012
13	Aerocube 4	Aerospace Corporation	USA	C	Technology	LEO	4	2012
14	Aerocube 5	Aerospace Corporation	USA	C	Technology	LEO	5	2012
15	Aerocube5B	Aerospace Corporation	USA	C	Tech.	LEO	5	2012
16	Africasat-1	MEASAT Satellite Systems	Malaysia	C	Communications	GEO	1,450	1996
17	Afristar 1	Worldspace	USA	C	Communications	GEO	2,704	1998
18	Agila 2	Asia Broadcast Satellite	International	C	Communications	GEO	3,775	1997
19	AGILE	Italian Space Agency	Italy	G	Sci Research	LEO	325	2007
20	AIM	Hampton University/NASA	USA	G	Sci	LEO	215	2007
21	AISSat-1	KSAT	Norway	G	Maritime	LEO	6	2010
22	Akebono	University of Tokyo	Japan	C	Space Physics	Ell	.	1989
23	Alsat-2A	CNTS	Algeria	G	Observation	LEO	130	2010
24	Amazonas	Hispamar	Brazil	C	Communications	GEO	4,545	2004
25	Amazonas-2	Hispasat	Spain	C	Communications	GEO	5,465	2009
26	AMC-1	SES	USA	C	Communications	GEO	2,783	1996
27	AMC-10	SES	USA	C	Communications	GEO	2,315	2004
28	AMC-11	SES	USA	C	Communications	GEO	2,340	2004
29	AMC-15	SES	USA	C	Communications	GEO	4,200	2004
30	AMC-16	SES	USA	C	Communications	GEO	4,312	2004
31	AMC-18	SES	USA	C	Communications	GEO	2,081	2006
32	AMC-2	SES	USA	C	Communications	GEO	2,648	1997
33	AMC-21	SES	USA	C	Communications	GEO	2,500	2008
34	AMC-3	SES	USA	C	Communications	GEO	2,845	1997
35	AMC-4	SES	USA	C	Communications	GEO	3,909	1999
36	AMC-5	SES	USA	C	Communications	GEO	1,698	1998
37	AMC-6	SES	USA	C	Communications	GEO	3,901	2000
38	AMC-7	SES	USA	C	Communications	GEO	1,935	2000
39	AMC-8	SES	USA	C	Communications	GEO	2,015	2000
40	AMC-9	SES	USA	C	Communications	GEO	4,100	2003
41	Amos 2	Israel Aircraft Industries	Israel	M/C	Communications	GEO	1,400	2003
42	Amos 3	Space-Communication Ltd	Israel	M/C	Communications	GEO		2008
43	Amos 5	Space-Communication Ltd	Israel	M/C	Communications	GEO	1,600	2011
44	Amsat-Oscar7	Amsat-NA	USA	Civ	Amateur Radio	LEO	29	1974
45	Anik F1	Telesat Canada Ltd.	Canada	C	Communications	GEO	4,710	2000
46	Anik F1R	Telesat Canada Ltd.	Canada	C	Communications	GEO	4,500	2005
47	Anik F2	Telesat Canada Ltd.	Canada	C	Communications	GEO	5,910	2004
48	Anik F3	Telesat Canada Ltd.	Canada	C	Communications	GEO	4,715	2007
49	AprizeSat 1	Aprize Satellites	Argentina	C	Communications	LEO	12	2004
50	AprizeSat 2	Aprize Satellites	Argentina	C	Communications	LEO	12	2004
51	AprizeSat 3	Latin Trade Satellite	USA/Argentina	C	Maritime Track	LEO	12	2009
52	AprizeSat 4	Latin Trade Satellite	USA/Argentina	C	Maritime Track	LEO	12	2009
53	AprizeSat 5	Latin Trade Satellite	USA/Argentina	C	Maritime Track	LEO	12	2011
54	AprizeSat 6	Latin Trade Satellite	USA/Argentina	C	Maritime Track	LEO	12	2011
55	Apstar 1	APT Satellite Holdings Ltd.	China (PR)	C	Communications	GEO	1,383	1994
56	Apstar 1A	APT Satellite Holdings Ltd.	China (PR)	C	Communications	GEO	1,383	1996
57	Apstar 6	APT Satellite Holdings Ltd.	China (PR)	C	Communications	GEO	4,680	2005
58	Apstar 7	APT Satellite Holdings Ltd.	China (PR)	C	Communications	GEO	5,054	2012
59	Arabsat 2B	ASCO	Multinational	G	Communications	GEO	2,661	1996
60	Arabsat 5C	ASCO	Multinational	G	Communications	GEO	4,630	2011
61	Artemis	European Space Agency	ESA	C/G	Research		GEO 3,105	2001
62	AsiaSat 3S	Asia SES	China (PR)	C	Communications	GEO	3,480	1999
63	AsiaSat 4	Asia SES	China (PR)	C	Communications	GEO	4,137	2003
64	AsiaSat 5	Asia SES	China (PR)	C	Communications	GEO	3,760	2009
65	AsiaSat 7	Asia SES	China (PR)	C	Communications	GEO	3,813	2011
66	AsiaStar	1Worldspace	USA	C	Communications	GEO	2,775	2000
67	Astra 1D	SES	Luxembourg	C	Communications	GEO	2,924	1994

68	Astra 1E	SES	Luxembourg	C	Communications	GEO	3,014	1995
69	Astra 1F	SES	Luxembourg	C	Communications	GEO	3,010	1996
70	Astra 1G	SES	Luxembourg	C	Communications	GEO	3,379	1997
71	Astra 1H	SES	Luxembourg	C	Communications	GEO	3,690	1999
72	Astra 1KR	SES	Luxembourg	C	Communications	GEO	4,332	2006
73	Astra 1L	SES	Luxembourg	C	Communications	GEO	4,500	2007
74	Astra 1M	SES	Luxembourg	C	Communications	GEO	5,345	2008
75	Astra 1N	SES	Luxembourg	C	Communications	GEO	5,350	2011
76	Astra 2A	SES	Luxembourg	C	Communications	GEO	3,635	1998
77	Astra 2B	SES	Luxembourg	C	Communications	GEO	3,315	2000
78	Astra 2C	SES	Luxembourg	C	Communications	GEO	3,643	2001
79	Astra 2D	SES	Luxembourg	C	Communications	GEO	1,420	2000
80	Astra 2F	SES	Luxembourg	C	Communicatins	GEO	6,000	2012
81	ABS-1	Asia Broadcast Satellite	International	C	Communications	GEO	2,894	1999
82	Astra 3A	SES	Luxembourg	C	Communications	GEO	1,500	2002
83	Astra 3B	SES	Luxembourg	C	Communications	GEO	5,471	2010
84	A.Bird 1	EUTELSAT	Multinational	C	Communications	GEO	2,700	2002
85	A. Bird 2	EUTELSAT	Multinational	C	Communications	GEO	3,150	2001
86	A. Bird 3	EUTELSAT	Multinational	C	Communications	GEO	4,050	2002
87	A. Bird 4	EUTELSAT	Multinational	C	Communications	GEO	2,885	1998
88	A. Bird 7	EUTELSAT/Nilesat	Multinational	C	Communications	GEO	4,600	2011
89	Badr 2	SUPARCO	Pakistan	G/M	Remote Sensing	LEO	70	2001

92 Pakistan's microsatellite for development of surveillance capability.

90	Badr 4	ASCO	Multinational	G	Communications	GEO	3,304	2006
91	Badr 5	ASCO	Multinational	G	Communications	GEO	5,420	2010
92	Badr 5A	ASCO	Multinational	G	Communications	GEO	4,940	2010

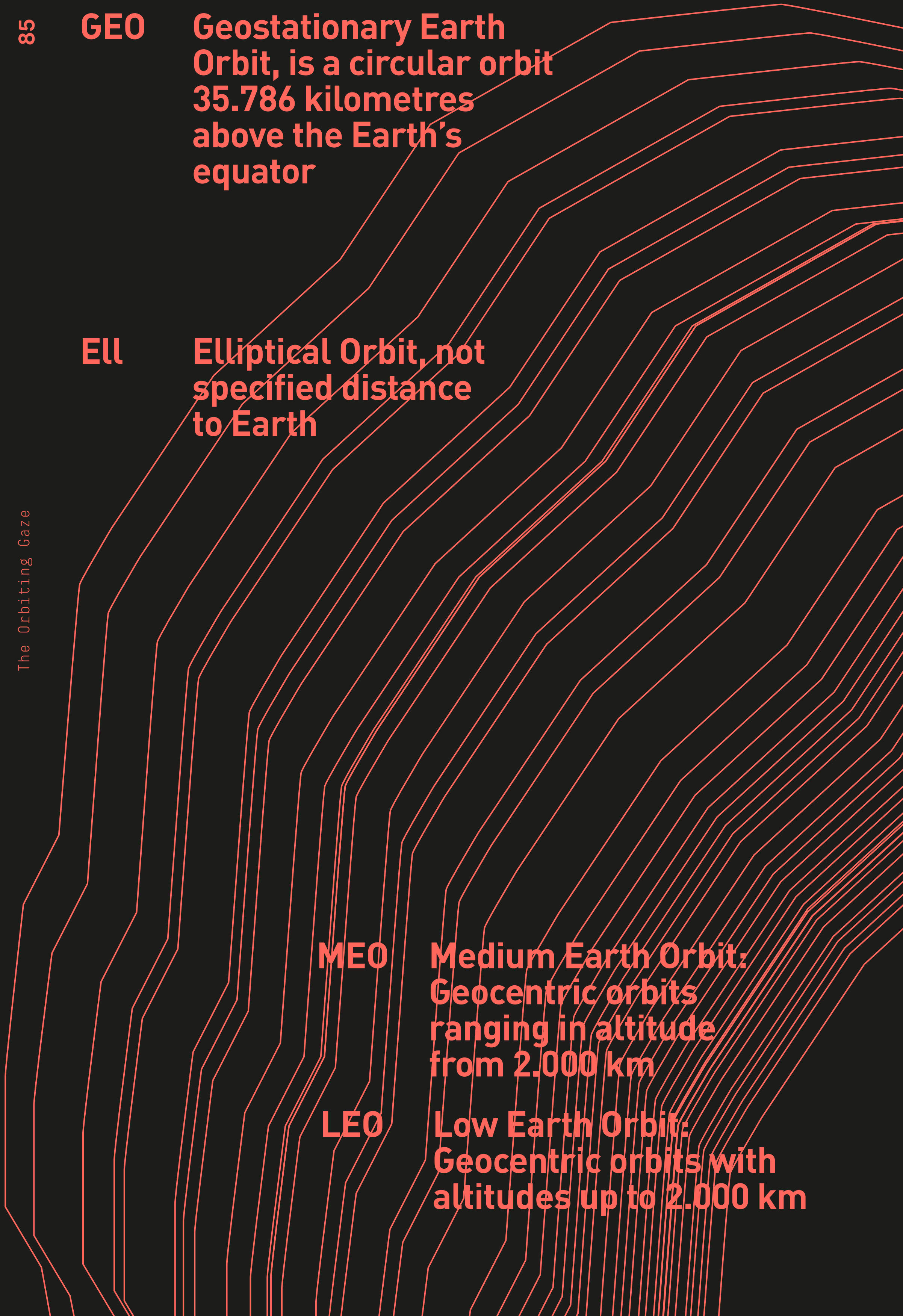
95 Space-based navigation and positioning system to improve accuracy of weapons and situational awareness of military forces.

93	Badr 6	ASCO	Multinational	G	Communications	GEO	3,400	2008
94	BeeSat	Institut für Luft/	Germany	Civ	Technology	LEO	1	2009
95	Beidou 1B	Defense Ministry	China (PR)	M	Global Position	GEO	2,200	2000
96	Beidou 1C	Ministry	China (PR)	M	Global Position	GEO	2,200	2003
97	Galaxy-1	BLMIT	China (PR)	Civ	Earth Observation	LEO	166	2005
98	Bird 2	Inst. of Space Technology	Germany	G/Civ	Remote Sensing	LEO	92	2001
99	BKA	National Academy of Sciences	Belarus	Gt	Remote Sensing	LEO	400	2012
100	Bonum 1	Intersputnik	Russia	C	Communications	GEO	1,452	1998
101	BrazilsatB-3	SES	Brazil	C	Communications	GEO	1,780	1998
102	BrazilsatB-4	SES	Brazil	C	Communications	GEO	2,495	2000
103	BSAT-2C	Broadcasting Satellite Corp.	Japan	C	Communications	GEO	1,275	2003
104	BSAT-3A	Broadcasting Satellite Corp.	Japan	C	Communications	GEO	1,980	2007
105	BSAT-3B	Broadcasting Satellite Corp.	Japan	C	Communications	GEO	2,060	2010

106	BSAT-3C/	Sky Perfect JSAT Corporation	Japan	C	Communications	GEO	2,910	2011
107	C/NOFS	US Air Force	USA	M	Tech. Development	LEO	384	2008
108	Cakrawarta 1	CSM	Indonesia	C	Communications	GEO	1,385	1997
109	Calipso	CNES/NASA	France/USA	G	Earth Science	LEO	587	2006
110	Canopus-B	Scientific Production Corp.	Russia	G	Remote Sensing	LEO	400	2012
111	CAN-X2	University of Toronto	Canada	Civ	Tech. Development	LEO	7	2008

114 Remote sensing and mapping; panchromatic images at one-meter resolution to be used for civil planning "and other cartographic needs" of military forces

112	CAN-X6	University of Toronto	Canada	Civ/C	Tech. Development	LEO	16	2008
113	CartoSat 1	ISRO	India	G	Remote Sensing	LEO	1,560	2005
114	CartoSat 2	ISRO	India	G	Remote Sensing	LEO	680	2007
115	CartoSat 2A	ISRO	India	M	Remote Sensing	LEO	680	2008
116	CartoSat 2B	ISRO	India	G	Remote Sensing	LEO	694	2010
117	CFESat	LANL	USA	G	Tech. Development	LEO	159	2007
118	Chandra	X-Ray Observatory (CXO)NASA	USA	G	Astrophysics	Ell	4,742	1999
119	ChinaSat 6B	China Satcom	China (PR)	C/G	Communications	GEO	4,600	2007
120	Chinastar-1	China Satcom	China (PR)	C/G	Communications	GEO	3,000	1998
121	Chuangxin 1	Chinese Academy of Sciences	China (PR)	G	Communications	LEO	100	2003
122	Chuangxin 2	Chinese Academy of Sciences	China (PR)	G	Earth Observation	LEO	101	2008
123	Chuangxin 3	Chinese Academy of Sciences	China (PR)	G	Earth Observation	LEO	100	2011
124	Ciel-2	Ciel Satellite Group	Canada	C	Communications	GEO	5,585	2008
125	CINEMA	Berkeley/Imperial College	USA	Ci	Space Science	LEO	3	2012
126	Cloudsat	NASA	USA	G/Civ	Earth Science	LEO	848	2006
127	Compass G-1	Chinese Defense Ministry	China (PR)	M	Navigation	GEO	2,200	2010
128	Compass G-10	Chinese Defense Ministry	China (PR)	M	Navigation	GEO	2,300	2011
129	Compass G-11	Chinese Defense Ministry	China (PR)	M	Navigation	GEO	2,300	2012
130	Compass G-2	Chinese Defense Ministry	China (PR)	M	Navigation	GEO	2,200	2009
131	Compass G-3	Chinese Defense Ministry	China (PR)	M	Navigation	GEO	2,200	2010
132	Compass G-4	Chinese Defense Ministry	China (PR)	M	Navigation	GEO	6,000	2010
133	Compass G-5	Chinese Defense Ministry	China (PR)	M	Navigation	GEO	2,200	2010
134	Compass G-6	Chinese Defense Ministry	China (PR)	M	Navigation	GEO	3,800	2012
135	Compass G-7	Chinese Defense Ministry	China (PR)	M	Navigation	GEO	2,200	2010
136	Compass G-8	Chinese Defense Ministry	China (PR)	M	Navigation	GEO	2,300	2011
137	Compass G-9	Chinese Defense Ministry	China (PR)	M	Navigation	GEO	2,300	2011
138	Compass M1	Chinese Defense Ministry	China (PR)	M	Navigation	MEO	2,200	2007
139	Compass M3	Chinese Defense Ministry	China (PR)	M	Navigation	MEO	2,200	2012
140	Compass M4	Chinese Defense Ministry	China (PR)	M	Navigation	MEO	2,200	2012
141	Compass M5	Chinese Defense Ministry	China (PR)	M	Navigation	MEO	3,800	2012
142	Compass M6	Chinese Defense Ministry	China (PR)	M	Navigation	MEO	3,800	2012
143	COMS-1	KARI	South Korea	G	Earth Observation	GEO	2,460	2010
144	COMSATBw-1	Armed Forces	Germany	M	Communications	GEO	2,440	2009
145	COMSATBw-2	Armed Forces	Germany	M	Communications	GEO	2,440	2010
146	Coriolis	US Air Force/ US Navy/NASA	USA	M	Science	LEO	817	2003
147	CoRoT	CNES	Multinational	G	Space Science	LEO	668	2006
148	COSMIC-A	NSPO/UCAR Boulder, CO	Taiwan/USA	G/Civ	Remote Sensing	LEO	70	2006
149	COSMIC-B	NSPO/UCAR Boulder, CO	Taiwan/USA	G/Civ	Remote Sensing	LEO	70	2006
150	COSMIC-D	NSPO/UCAR Boulder, CO	Taiwan/USA	G/Civ	Remote Sensing	LEO	70	2006
151	COSMIC-E	NSPO/UCAR Boulder, CO	Taiwan/USA	G/Civ	Remote Sensing	LEO	70	2006
152	COSMIC-F	NSPO/UCAR Boulder, CO	Taiwan/USA	G/Civ	Remote Sensing	LEO	70	2006
153	COSMO-Sk 1	Italian Space Agency/Gov	Italy	G/Civ	Remote Sensing	LEO	1,700	2007
154	COSMO-Sk 2	Italian Space Agency/Gov	Italy	G/Civ	Earth Observation	LEO	1,700	2007
155	COSMO-Sk3	Italian Space Agency/Gov	Italy	G/Civ	Earth Observation	LEO	1,700	2008
156	COSMO-Sk 4	Italian Space Agency/Gov	Italy	G/Civ	Earth Observation	LEO	1,700	2010



GEO Geostationary Earth Orbit, is a circular orbit 35.786 kilometres above the Earth's equator

Ell Elliptical Orbit, not specified distance to Earth

MEO Medium Earth Orbit: Geocentric orbits ranging in altitude from 2.000 km

LEO Low Earth Orbit: Geocentric orbits with altitudes up to 2.000 km

157	CP-5	Cal. Polytechnic University	USA	C	Tech. Development	LEO	1	2012
158	Cryosat-2	ESA	ESA	G	Earth Observation	LEO	720	2010
159	CSSWE	University of Colorado	USA	C	Earth Science	LEO	3	2012
160	CubesatXI-IV	University of Tokyo	Japan	C	Tech. Development	LEO		2003
161	Cubesat XI-V	University of Tokyo	Japan	C	Tech. Development	LEO	1	2005
162	Cute-1	Tokyo Inst. of Technology	Japan	C	Tech. Development	LEO		2003
163	Cute 1.7 2	Tokyo Inst. of Technology	Japan	C	Tech. Development	LEO		2008
164	CXBN	Morehead State University	USA	C	Earth Science	LEO	3	2012
165	Deimos 1	DMCII	Spain	G	Earth Observation	LEO	90	2009
166	Delfi-C3	Technical University, Delft	Netherlands	C	Tech Development	LEO	7	2008
167	DirecTV-10	DirecTV, Inc.	USA	C	Communications	GEO	5,900	2007
168	DirecTV-11	DirecTV, Inc.	USA	C	Communications	GEO	5,900	2008
169	DirecTV-12	DirecTV, Inc.	USA	C	Communications	GEO	5,900	2009
170	DirecTV-4S	DirecTV, Inc.	USA	C	Communications	GEO	4,300	2001
171	DirecTV-5	DirecTV, Inc.	USA	C	Communications	GEO	4,300	2002
172	DirecTV-7S	DirecTV, Inc.	USA	C	Communications	GEO	5,483	2004
173	DirecTV-8	DirecTV, Inc.	USA	C	Communications	GEO	3,800	2005
174	DirecTV-9S	DirecTV, Inc.	USA	C	Communications	GEO	5,500	2006
175	DLR Tubsat	Zentrum für Raumfahrt	Germany	G	Earth Science	LEO	45	1999
176	USA 109	DoD/NOAA	USA	M	Meteorology	LEO	1,134	1995
177	USA 131	DoD/NOAA	USA	M	Meteorology	LEO	1,134	1997
178	USA 147	DoD/NOAA	USA	M	Meteorology	LEO	1,152	1999
179	USA 172	DoD/NOAA	USA	M	Meteorology	LEO	1,154	2003
180	USA 191	DoD/NOAA	USA	M	Meteorology	LEO	1,154	2006
181	USA 210	DoD/NOAA	USA	M	Meteorology	LEO	1,155	2009
182	DRTS	National Space Devel. Agency	Japan	G	Tech. Development	GEO	2,650	2002
183	USA 167	US Air Force	USA	M	Communications	GEO	1,156	2003
184	USA 170	US Air Force	USA	M	Communications	GEO	1,156	2003
185	USA 135	US Air Force	USA	M	Communications	GEO	1,156	1997
186	USA 148	US Air Force	USA	M	Communications	GEO	1,156	2000
187	USA 153	US Air Force	USA	M	Communications	GEO	1,156	2000
188	USA 82	US Air Force	USA	M	Communications	GEO	1,156	1992
189	USA 97	US Air Force	USA	M	Communications	GEO	1,156	1993
190	USA 113	US Air Force	USA	M	Communications	GEO	1,156	1995
191	USA 130	Air Force	USA	M	Early Warning	GEO	2,380	1997
192	USA 149	Air Force	USA	M	Early Warning	GEO	2,380	2000
193	USA 159	Air Force	USA	M	Early Warning	GEO	2,380	2001
194	USA 176	Air Force	USA	M	Early Warning	GEO	2,380	2004
195	DubaiSat 1	Emirates Institution EIAST	UAE	G	Earth Observation	LEO	200	2009
196	E-bird	EUTELSAT	Multinational	C	Communications	GEO	1,525	2003
197	Echostar 1	QuetzSat, S. de R.L. de C.V.	Mexico	C	Communications	GEO	3,287	1995
198	Echostar 10	Echostar Technologies, LLC	USA	C	Communications	GEO	4,333	2006
199	Echostar 11	Echostar Technologies, LLC	USA	C	Communications	GEO	5,500	2008
200	Echostar 12	Echostar Technologies, LLC	USA	C	Communications	GEO	4,328	2003
201	Echostar 14	Echostar Technologies, LLC	USA	C	Communications	GEO	6,384	2010
202	Echostar 15	Echostar Technologies, LLC	USA	C	Communications	GEO	5,521	2010
203	Echostar 16	Echostar Technologies, LLC	USA	C	Communications	GEO	6,658	2012
204	Echostar 17	Echostar Technologies, LLC	USA	C	Communications	GEO	6,100	2012
205	Echostar 3	Echostar Technologies, LLC	USA	C	Communications	GEO	3,674	1997
206	Echostar 6	Echostar Technologies, LLC	USA	C	Communications	GEO	3,700	2000
207	Echostar 7	Echostar Technologies, LLC	USA	C	Communications	GEO	4,027	2002
208	Echostar 8	Echostar Technologies, LLC	USA	C	Communications	GEO	4,660	2002
209	Echostar 9	Echostar Technologies, LLC	USA	C	Communications	GEO	4,000	2003
210	Echostar G1	Dish Network	USA	C	Communications	GEO	6,600	2008
211	EduSAT	University of Rome	Italy	Civ	Tech. Development	LEO	10	2011
212	Electro-L1	Roshydromet - Planeta	Russia	G	Meteorological	GEO	1,766	2011
213	ELISA-E12	DGA / CNES	France	M	Intelligence	LEO	120	2011
214	ELISA-E24	DGA / CNES	France	M	Intelligence	LEO	120	2011
215	ELISA-W11	DGA / CNES	France	M	Intelligence	LEO	120	2011
216	ELISA-W23	DGA / CNES	France	M	Intelligence	LEO	120	2011
217	EO-1	NASA Earth Science Office	USA	G	Earth Observation	LEO	572	2000
218	Terra	NASA	USA/Canada/Japan	G	Earth Science	LEO	4,854	1999
219	Aura	Goddard Space Center/EOS	USA	G	Remote Sensing	LEO	2,967	2004
220	Aqua	Div national space agencies	USA/Japan/Brazil	G	Earth Observation	LEO	2,934	2002
221	EROS A-1	NV/Ministry of Defense	Israel	M/C	Remote Sensing	LEO	240	2000
222	EROS B-1	NV/Ministry of Defense	Israel	M/C	Remote Sensing	LEO	350	2006
223	e-st@r	Politecnico di Torino	Italy	Civ	Tech. Development	Ell		2012
224	Eurasiasat 1	Eurasiasat SAM/Alcatel Space	Turkey/France	C	Communications	GEO	3,535	2001
225	Eurobird 1	EUTELSAT	Multinational	C	Communications	GEO	2,950	2001
226	Eurobird 2	EUTELSAT	Multinational	C	Communications	GEO	2,995	1998
227	Eurobird 9A	EUTELSAT	Multinational	C	Communications	GEO	4,100	2006
228	Europe*Star1	Europe*Star	Multinational	C	Communications	GEO	4,167	2000
229	EutelsatW-2A	EUTELSAT	Multinational	C	Communications	GEO	5,9000	2009
230	EutelsatW-2A	EUTELSAT	Multinational	C	Communications	GEO	5,9000	2009

231	Eutelsat W2M	EUTELSAT	Multinational	C	Communications	GEO	3,460	2008
232	Eutelsat W-3A	EUTELSAT	Multinational	C	Communications	GEO	4,300	2004
233	Eutelsat W4	EUTELSAT	Multinational	C	Communications	GEO	3,190	2000
234	Eutelsat W48	EUTELSAT	Multinational	C	Communications	GEO	2,915	1996
235	Eutelsat W-5	EUTELSAT	Multinational	C	Communications	GEO	3,170	2002
236	Eutelsat W-6	EUTELSAT	Multinational	C	Communications	GEO	2,490	1999
237	Eutelsat W6A	EUTELSAT	Multinational	C	Communications	GEO	5,102	2012
238	Eutelsat W-7	EUTELSAT	Multinational	C	Communications	GEO	5,600	2009
239	Eutelsat WC3	EUTELSAT	Multinational	C	Communications	GEO	5,400	2011
240	exactView 1	ExactEarth	Canada	C	Maritime Tracking	LEO	100	2012
241	Express AM22	Intersputnik/EUTELSAT	Russia/Multinational	C	Communications	GEO	2,600	2003
242	Express-2A	Intersputnik	Russia	C	Communications	GEO	2,600	2000
243	Express-A1R	Intersputnik	Russia	C	Communications	GEO	2,600	2002
244	Express-AM1	Intersputnik	Russia	C	Communications	GEO	2,600	2004
245	Express-AM2	Intersputnik	Russia	C	Communications	GEO	2,542	2005
246	Express-AM3	Intersputnik	Russia	C	Communications	GEO	2,600	2005
247	Express-AM33	Intersputnik	Russia	C	Communications	GEO	2,600	2008
248	Express-AM44	Intersputnik	Russia	C	Communications	GEO	2,532	2009
249	Express-MD1	Intersputnik	Russia	C	Communications	GEO	1,140	2009
250	Falconsat-3	US Air Force Academy	USA	Civ/M	Tech. Development	LEO	46	2007
251	USA 222	University of Texas	USA	Civ	Tech. Development	LEO	55	2010
252	Fengniao 1	CAST	China (PR)	G	Tech. Development	LEO		2012
253	Fengniao 1A	CAST	China (PR)	G	Tech. Development	LEO		2012
254	FY-1D	China Meteorological Admin.	China (PR)	G	Earth Science	LEO	956	2002
255	FY-2D	China Meteorological Admin.	China (PR)	G	Earth Science	GEO	1,390	2006
256	FY-2E	China Meteorological Admin.	China (PR)	G	Earth Science	GEO	1,390	2008
257	FY-2F	China Meteorological Admin.	China (PR)	G	Earth Science	GEO	1,390	2012
258	FY-3A	China Meteorological Admin.	China (PR)	G	Earth Science	LEO	2,300	2008
259	FY-3B	China Meteorological Admin.	China (PR)	G	Earth Science	LEO	2,300	2010
260	Fermi G-R	NASA/GSFC	USA	G	Astrophysics	LEO	4,303	2008
261	USA 215	NRO	USA	M	Reconnaissance	LEO		2010
262	USA 234	NRO	USA	M	Reconnaissance	LEO		2012

260-61

Amateur observers speculate that this is part of the reconnaisance program ‘Future Imagery Architecture,’ FIA.

263	USA 46	US Navy	USA	M	Communications	GEO	2,310	1989
264	Formosat-2	NSPO	Taiwan	G/M	Remote Sensing	LEO	764	2004
265	FORTÉ	Los Alamos National Labs/DOE	USA	G	Earth Observation	LEO	215	1997
266	Galaxy-11	PanAmSat (Intelsat, Ltd.)	USA	C	Communications	GEO	4,488	1999
267	Galaxy-12	PanAmSat (Intelsat, Ltd.)	USA	C	Communications	GEO	1,760	2003
268	Galaxy-13	Intelsat, Ltd.)/JSAT Corp.	USA/Japan	C	Communications	GEO	4,060	2003
269	Galaxy-14	PanAmSat (Intelsat, Ltd.)	USA	C	Communications	GEO	2,086	2005
270	Galaxy-15	PanAmSat (Intelsat, Ltd.)	USA	C	Communications	GEO	2,033	2005
271	Galaxy-16	PanAmSat (Intelsat, Ltd.)	USA	C	Communications	GEO	4,640	2006
272	Galaxy-17	Intelsat, Ltd.	USA	C	Communications	GEO	4,100	2007
273	Galaxy-18	Intelsat, Ltd.	USA	C	Communications	GEO	4,642	2008
274	Galaxy-19	Intelsat, Ltd.	USA	C	Communications	GEO	4,690	2008
275	Galaxy-25	Intelsat, Ltd.	USA	C	Communications	GEO	3,515	1997
276	Galaxy-26	Intelsat, Ltd.	USA	C	Communications	GEO	3,765	1999
277	Galaxy-27	Intelsat, Ltd.	USA	C	Communications	GEO	3,790	1999
278	Galaxy-28	Intelsat, Ltd.	USA	C	Communications	GEO	5,493	2005
279	Galaxy-3C	PanAmSat (Intelsat, Ltd.)	USA	C	Communications	GEO	4,860	2002
280	GALEX	Calif. Inst. of Tech./NASA	USA	G/C	Space Science	LEO	280	2003
281	Galileo IOV	European Space Agency	ESA	C	Navigation	MEO	700	2011
282	Galileo IOV1	European Space Agency	ESA	C	Navigation	MEO	700	2011
283	Galileo IOV2	European Space Agency	ESA	C	Navigation	MEO	700	2012
284	Galileo IOV2	European Space Agency	ESA	C	Navigation	MEO	700	2012
285	Cosmos 2473	Ministry of Defense	Russia	M	Communications	GEO	5,000	2011
286	Garuda-1	Asia Cellular Satellite	IN/PH/TH	C	Communications	GEO	4,291	2000

287	GE-23	SAT-GE	USA	C	Communications	GEO	5,000	2005
288	Genesis-1	Bigelow Aerospace	USA	C	Tech. Development	LEO	1,360	2006
289	Genesis-2	Bigelow Aerospace	USA	C	Tech. Development	LEO	1,360	2007
290	GeoEye-1	GeoEye	USA	C/G	Remote Sensing	LEO	1,955	2008
291	USA 158	NRO	USA	M	Communications	GEO	1,800	2001
292	Geotail	ISAS/NASA/ESA	Multinational	G	Space Physics	Ell	980	1992
293	GCOM-1	JAXA	USA/Japan	G	Earth Science	LEO	1,900	2012
294	G.FM4	Globalstar	USA	C	Communications	LEO	450	1998
295	G.star FM8	Globalstar	USA	C	Communications	LEO	450	1998
296	G.star M023	Globalstar	USA	C	Communications	LEO	450	1999
297	G.star M025	Globalstar	USA	C	Communications	LEO	450	1999
298	G.star M027	Globalstar	USA	C	Communications	LEO	450	1999
299	G.star M028	Globalstar	USA	C	Communications	LEO	450	1999
300	G.star M029	Globalstar	USA	C	Communications	LEO	450	1999
301	G.star M031	Globalstar	USA	C	Communications	LEO	450	1999
302	G.star M032	Globalstar	USA	C	Communications	LEO	450	1999
303	G.star M031	Globalstar	USA	C	Communications	LEO	450	1999
304	G.star M033	Globalstar	USA	C	Communications	LEO	450	1999
305	Gl.star FM37	Globalstar	USA	C	Communications	LEO	450	1999
306	G.star M039	Globalstar	USA	C	Communications	LEO	450	1999
307	G.star M040	Globalstar	USA	C	Communications	LEO	450	1999
308	G.star M045	Globalstar	USA	C	Communications	LEO	450	1999
309	G.star M047	Globalstar	USA	C	Communications	LEO	450	1999
310	G.star M052	Globalstar	USA	C	Communications	LEO	450	1999
311	G.star M056	Globalstar	USA	C	Communications	LEO	450	1999
312	G.star M059	Globalstar	USA	C	Communications	LEO	450	1999
313	G.star M063	Globalstar	USA	C	Communications	LEO	450	2000
314	G.star M065	Globalstar	USA	C	Communications	LEO	450	2007
315	G.star M066	Globalstar	USA	C	Communications	LEO	450	2007
316	G.star M067	Globalstar	USA	C	Communications	LEO	450	2007
317	G.star M068	Globalstar	USA	C	Communications	LEO	450	2007
318	G.star M069	Globalstar	USA	C	Communications	LEO	450	2007
319	G.star M070	Globalstar	USA	C	Communications	LEO	450	2007
320	star M071	Globalstar	USA	C	Communications	LEO	450	2007
321	G.star M072	Globalstar	USA	C	Communications	LEO	450	2007
322	G.star M073	Globalstar	USA	C	Communications	LEO	700	2010
323	G.star M074	Globalstar	USA	C	Communications	LEO	700	2010
324	G.star M075	Globalstar	USA	C	Communications	LEO	700	2010
325	G.star M076	Globalstar	USA	C	Communications	LEO	700	2010
326	G.star M077	Globalstar	USA	C	Communications	LEO	700	2010
327	G.star M079	Globalstar	USA	C	Communications	LEO	700	2010
328	G.star M080	Globalstar	USA	C	Communications	LEO	700	2011
329	G.star M081	Globalstar	USA	C	Communications	LEO	700	2011
330	G.star M082	Globalstar	USA	C	Communications	LEO	700	2011
331	G.star M083	Globalstar	USA	C	Communications	LEO	700	2011
332	G.star M084	Globalstar	USA	C	Communications	LEO	700	2011
333	G.star M085	Globalstar	USA	C	Communications	LEO	700	2011
334	G.star M086	Globalstar	USA	C	Communications	LEO	700	2011
335	G.star M088	Globalstar	USA	C	Communications	LEO	700	2011
336	G.star M089	Globalstar	USA	C	Communications	LEO	700	2011
337	G.star M090	Globalstar	USA	C	Communications	LEO	700	2011
338	G.star M091	Globalstar	USA	C	Communications	LEO	700	2011
339	G.star M092	Globalstar	USA	C	Communications	LEO	700	2011
340	Cosmos 2471	Ministry of Defense	Russia	M/C	Navigation	MEO	935	2011
341	Cosmos 2413	Ministry of Defense	Russia	M/C	Navigation	MEO	1,480	2004
342	Cosmos 2419	Ministry of Defense	Russia	M/C	Navigation	MEO	1,480	2005
343	Cosmos 2424	Ministry of Defense	Russia	M/C	Navigation	MEO	1,480	2006
344	Cosmos 2425	Ministry of Defense	Russia	M/C	Navigation	MEO	1,480	2006
345	Cosmos 2426	Ministry of Defense	Russia	M/C	Navigation	MEO	1,480	2006
346	Cosmos 2432	Ministry of Defense	Russia	M/C	Navigation	MEO	1,480	2007
347	Cosmos 2433	Ministry of Defense	Russia	M/C	Navigation	MEO	1,480	2007
348	Cosmos 2434	Ministry of Defense	Russia	M/C	Navigation	MEO	1,480	2007
349	Cosmos 2435	Ministry of Defense	Russia	M/C	Navigation	MEO	1,480	2007
350	Cosmos 2436	Ministry of Defense	Russia	M/C	Navigation	MEO	1,480	2007
351	Cosmos 2442	Ministry of Defense	Russia	M/C	Navigation	MEO	1,480	2008
352	Cosmos 2443	Ministry of Defense	Russia	M/C	Navigation	MEO	1,480	2008
353	Cosmos 2444	Ministry of Defense	Russia	M/C	Navigation	MEO	1,480	2008
354	Cosmos 2447	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2008
355	Cosmos 2448	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2008
356	Cosmos 2449	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2008
357	Cosmos 2456	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2009
358	Cosmos 2459	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2010
359	Cosmos 2460	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2010
360	Cosmos 2457	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2009

CYBERNETICS AND THE POLITICS OF THE DARK UNIVERSE

Andrew Pickering

Modern science reveals what the consistencies are, enabling us to control the world and refashion it to suit our own ends. Politically, this is a vision of the world that many want to escape. In his lecture at Sonic Acts, Andrew Pickering argued that this is where cybernetics comes in. Cybernetics begins from the assumption that the world is ultimately unknowable, a place of emergence and becoming that will always surprise us. This essay is a reworked version of Pickering's lecture at Sonic Acts in 2013.

My topic is cybernetics, this strange science that reached a sort of peak in the 1960s – the time of the counterculture – and is now making quite a comeback amongst artists and academics. I want to explore what draws people to cybernetics by pointing to its relation to the theme of the dark universe. And I am especially interested here in the politics of cybernetics. Donna Haraway famously ended her *Manifesto for Cyborgs* with the declaration that 'I would rather be a cyborg than a goddess'. I wrote a book, *The Cybernetic Brain,* with the optimistic subtitle *Sketches of Another Future*. Like Haraway, I think of cybernetics as the best hope we have for finding new ways to act and think. But whenever I say that in public, someone stands up and explains that cybernetics is politically repellent: 'Cybernetics is the police-like thinking of the Empire, entirely animated by an offensive concept of politics … Cybernetics is war against all that lives and all that is lasting'.[1] So I want to understand how these totally opposed political evaluations can both exist.

The allure of cybernetics

First, the allure of cybernetics – what draws people to it? The answer is: it's different. It's a different kind of science. It belongs to a strange and unfamiliar paradigm, in Thomas Kuhn's sense, almost an anti-paradigm. But what does that imply? I find it easiest to think about ontology here, meaning, very simply, visions of what the world is like. We teach our children to think of the world as a knowable, regular, law-like and predictable place. The modern sciences find out what the regularities are and thus put us in a position to control the world and refashion it to suit our own ends. This is the project, the stance, the way of getting on in the world, that Martin Heidegger called enframing – dominating the world through knowledge – which comes very naturally to all of us.[2] The physicist Gerard 't Hooft finds it unproblematic to speak of the 'colonisation' of the solar system.[3] Politically, this colonising stance is what I, Haraway and many others want to get away from. This is where cybernetics comes in. Its ontology is different. It begins with the assumption that the world is ultimately *unknowable*, an unpredictable place of emergence and becoming that will always surprise us. For physicists and cosmologists, the discovery that 95% of the universe is mysterious 'dark matter' and 'dark energy', is a self-generated challenge – they want to tame the mystery and make it predictable. For the cyberneticians, in contrast, we live in a 'dark universe', full stop.

1. Tiqqun, n.d., p. 8.
2. Heidegger, 1977.
3. Gerard 't Hooft talked about this in his presentation at the 2013 Sonic Acts Festival.

This, then, is the source of cybernetics' allure – it offers us a different image of what the world is like, which invites us to rethink from scratch all of the traditional academic, artistic and, certainly, political problematics. This is why Haraway would rather be a cyborg – a cybernetic organism – than a goddess. But just what does the cyborg speak to us about? Before we get to that, one more general remark is needed. If the task of the modern sciences is to produce positive knowledge and make the world more knowable, what is the task of cybernetics? Given its ontology of unknowability, it can hardly be to produce a conventional kind of positive knowledge. Instead cybernetics has focused on ways of getting to grips with and getting along in a world that can always surprise us. That is why cybernetics has always been centred on adaptive machines and devices and strategies that cope with uncertainty, and with the overall theme of control. This obsession with control is the starting point for the critique, but to get to that we need to move down a level, from ontological generalities to cybernetics in action.

The thermostat

Cybernetics got its name from Norbert Wiener's 1948 book, *Cybernetics, or Control and Communication in the Animal and the Machine*, which brought together strands of work in feedback control, information theory and electronic computing dating back to World War II. We need to focus on feedback. Explanations of this concept always centre on the thermostat, the gadget that turns the heating on when a room gets too cold, and switches it off when it reaches the target temperature. The thermostat is a feedback device inasmuch as it detects the effects produced by some other machine (the heating system) and returns, feeds back, a signal dependent on that to control the machine itself.

Thermostats are easily understood and rather boring, but we can make them more interesting. First, we can understand them as playing out the cybernetic ontology of unknowability. The thermostat does not inhabit the knowable, calculable and predictable world described by modern physics. Its universe is always dark – unpatterned and chaotic, the random fluctuations of temperature in a room. Thinking about the thermostat is thus a way to begin to grasp the cybernetic ontology – simply imagine we live in a world built from random fluctuations rather than fixed entities like quarks, DNA or the physicists' dark matter. We can also find here an instance of the cybernetic focus on coping with unknowability – the thermostat is not powerless in its chaotic world; it just reacts on the fly to whatever comes along.

Second, we can make the thermostat more interesting by generalising from it, as Wiener, Arturo Rosenbleuth and Julian Bigelow did in 1943 in a paper entitled 'Behavior, Purpose, and Teleology'. They argued that the thermostat has a purpose – to keep room temperature constant – and that it can therefore be understood as a model for purposive behaviour in general, in animals and even human beings as well as machines. Cats, dogs, people – they are all feedback-control devices that try to achieve their goals in an error-correcting fashion. Here we find the beginnings of the cyborg theme – setting humans and nonhumans on the same plane; denying the specialness of the human that goes with the modern ontology.[4] This, again, is a characteristic cybernetic move, generalising from specific devices to an overall ontological picture: humanity as a feedback device in a chaotic world.

And third, this move opens the way for political critique. The political question is: how should we live our lives and organise society; here, what would cybernetics look like if we played it out as a blueprint for a social world? The critical argument is that it would be a disaster, a horror-show.[5] In particular, it is easy to see how discussions of the thermostat resonate with visions of social control, with thermostat-like mechanisms sitting on top of and optimising the performance of existing control mechanisms: the police, the army, all those disciplinary apparatuses that fascinated and repelled Michel Foucault, that Haraway and I want to escape from. In the early days this critique was articulated in visions of giant artificial cybernetic brains of superhuman intelligence taking command of society.[6]

The cybernetic brain is not a topic I can explore here, but it is not what we need to worry about anyway. As Tiqqun's critique argues very forcefully, neo-liberalism has developed its own endless list of petty mechanisms of cybernetic control: watching, detecting deviations from the programme, reacting to them with more or less subtle, more or less brutal rewards, punishments, sortings and expulsions.[7] One thinks of Gilles Deleuze's remarks on 'control society';[8] I personally think of the

4. Pickering, 2008.
5. Another line of critique that I will not explore here concerns cybernetics directly as engineering. Feedback control is central to industrial and military automation, leading to deskilling and unemployment (as Wiener, 1967, warned) and to the pilotless drone-strikes currently multiplying around the world. We could think of these as comprising some of the hardware of the control society, discussed below.
6. Dubarle, 1948.
7. This image of feedback control runs through Tiqqun's essay: 'Lyotard explains it: "there is, in all cybernetic systems, a unity of reference that permits one to measure the disparity produced by the introduction of an event within the system, and then… to annul this disparity… We see how the adoption of this perspective on society, that is, of the despotic fantasies of the masters, of placing themselves at the supposed location of the central zero, and thus identifying themselves with the matrix of Nothingness… must force one to extend one's ideas of threat and thus of defence". […] For a cybernetician, any disorder can only come from there having been a discrepancy between the pre-set behaviors and the real behaviors of the system's elements'. To resist control, 'I do not respond to the human or mechanical feedback loops that attempt to encircle me/figure me out… the feedback does not take place and a line of flight begins to be drawn'. (Tiqqun, n.d., pp. 22, 42, 46).
8. Deleuze, 1992.

management of English universities as a perfect example of this sort of cybernetic apparatus. And the picture only becomes more sinister when one observes that what escapes this sort of cybernetic analysis are precisely the goals and purposes of feedback systems. Early cybernetics took it for granted that the thermostat tries to keep the temperature constant at, say, 21 degrees Celsius – that number is simply a given, supplied from outside the system. No great analogical leap is required to get from there to a society governed by a small group of politicians, bankers and media men – Marx's blood-sucking vampires – setting the control parameters for their own benefit. This sounds to me like the world we live in right now, a world that all right-thinking people want to escape from.

Thus the critique: thermostat-cybernetics motivates, operationalises and naturalises a society of control and colonisation. I have no idea whether contemporary neo-liberalism owes anything historically to cybernetics. Probably not, probably it just accumulated piecemeal. And yet, it seems clear that a control society is where one could easily end up if one followed the drift of Wiener-style, thermostat-inspired cybernetics. The standard critique is unstoppable here; I think we should accept it. But it is important that there are other threads of cybernetics to think about, with different political implications.

The homeostat

If feedback control modelled on servomechanisms like the thermostat was at the heart of Wiener's cybernetics, other machines were central to other lines of cybernetic development. Two machines constructed in 1948, the same year that Wiener's *Cybernetics* was published, come immediately to mind: Grey Walter's robot tortoise and Ross Ashby's homeostat. The tortoises have been exemplary for subsequent developments in engineering (situated robotics) and the arts, but I will focus on Ashby's homeostat.

The homeostat was an electro-mechanical device that processed an input current, turning it into an electrical output. Its key feature was that if the current within it exceeded some preset value, a relay would trip and a switch would change the internal wiring – the machine would randomly reconfigure itself. Any single homeostat was inert and lifeless, but Ashby constructed multi-homeostat set-ups so that the outputs from each unit were the inputs to the others. When first switched on, such set-ups were typically unstable – the currents within the units tended to grow – but then the relays would start tripping and carry on doing so until the currents tended to vanish and the set up became stable and quiescent. That's it.

The homeostat sounds almost as boring as the thermostat, but Wiener described it as 'one of the great philosophical contributions of the present day'[9] – why? What did he mean? Like the thermostat, the homeostat exemplifies the cybernetic ontology of unknowability. In a multi-unit set-up, none of the units knew what would come back to it from the others; it simply reacted to whatever turned up. So the homeostat again fosters an image of the world as fluctuating and chaotic, not regular and law-like. But while thermostats are hard-wired and purely reactive, homeostats were more like agents. They actively explored the unknown, via their output currents; and they reacted constructively to whatever came back by reconfiguring themselves. They engaged in *dances of agency* with the other homeostats, as I would put it, to make a connection back to my earlier work in science studies.[10] This is a new and richer cybernetic vision of the world than that conjured up by the thermostat; now of lively agents engaged in responsive and transformative interactions with the world, and it is the vision enacted in a largely British tradition of cybernetics associated with names like Walter, Ashby, Gregory Bateson, Stafford Beer and Gordon Pask, which I explored in *The Cybernetic Brain*.

Asymmetric and symmetric cybernetics

With the homeostat in mind, we can return to the question of political critique. Again the question is: what would homeostat-style cybernetics look like if we lived it out? The answer is not entirely straightforward. Like Wiener, Ashby was happy to generalise from his device to the world in general. In fact, he understood the homeostat as a crude model for the brain, which might explain the early fears of artificial super-brains.[11] But in the present context it is important to recognise that he experimented with two sorts of multi-unit set-ups, symmetric and asymmetric ones. In the symmetric configuration, all of the units were free to adapt to the others; in asymmetric arrangements, the internal parameters of one unit were fixed and the others had to try to adapt around it. Ashby was a medical man and his career until 1960 was in a materialist form of psychiatric research. The 1940s and 1950s were the days of the 'great and desperate cures' in psychiatry: insulin and electric shock therapy and lobotomy, and Ashby understood these on the asymmetric model. The doctor had to be firm and unchanging while forcing the patient through a series of homeostat-like reconfigurations, via electric shocks to the brain or whatever, until, with luck, the patient arrived at a state resembling normality as defined by the doctor.

9. Wiener, 1967, p. 54.
10. Pickering, 1995
11. Ashby, 1948 and 1952.

This thread of cybernetic development has not received much critical attention – the critics have not really gone beyond the thermostat – but it is clear that same critique applies. The asymmetric thread of homeostat-cybernetics can underpin and naturalise even more brutal and heavy-handed forms of social control than the precisely calibrated feedback of thermostat-cybernetics. This is clear as a form of brutal psychiatry operating at the level of individuals; at the macro-level it seems like a good description of American, West-European and Israeli foreign policy in the Middle East, trying to shock the Iraqis, Afghanis or Palestinians into some political state we find acceptable.[12] 'Cybernetics is the police-like thinking of the Empire', to repeat the quote.[13]

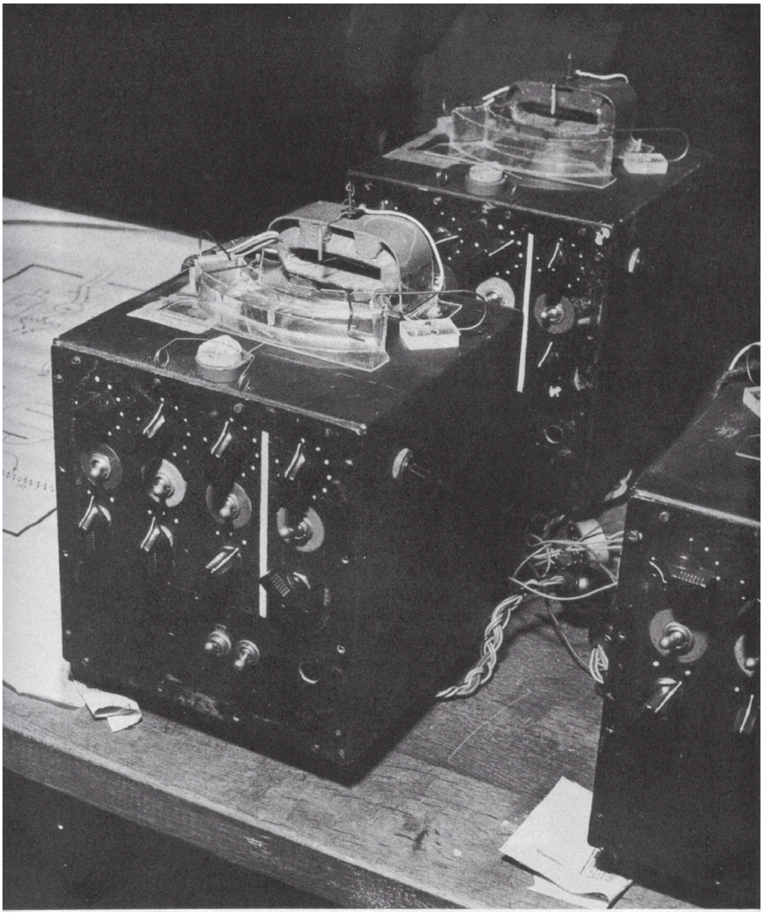
Which leaves us with the symmetric version of Ashby's cybernetics. If he analogised his asymmetric set-ups to psychiatry and, in fact, warfare, he could also imagine social transpositions of the symmetric set-ups, too. He discussed planning as a symmetric dance of agency between planners and plannees, in which the plans themselves were at stake and liable to revision, instead of being unilaterally imposed by one side on the other. Ontologically, the picture that emerges here is a one of forward-looking experimentation in which, like Ashby's homeostats, all of the agents involved, including human ones, continually change, mutate and become something new in processes of reciprocal engagement and adaptation – a neo-Taoist image of endless decentred flows and becomings.

A cybernetic politics of practice

This is where I wanted to get to, and now we can ask the political question again: what would this symmetric picture look like if we staged it in real life, if we tried to live it out? The first answer would have to be: nothing like the control society feared and despised by the critics of cybernetics. Open-ended experimentation is the antithesis of thermostat-style control.[14] It points to a continuous exploratory openness to what the world has to offer us, a stance of poiesis and revealing at the opposite pole from Heidegger's notion of enframing and 't Hooft's colonial imperative.[15] Politically then, as lived out, a symmetric homeostat-style cybernetics foreshadows a very different world from a control society and

12. Klein (2007) generalises this picture as a very plausible analysis of the characteristic mode of action of neoliberal capitalism.
13. By Tiqqun, n.d., p. 8
14. Symmetric cyberneticians like Gordon Pask continued to refer to 'control', and Stephen Willats even founded an art magazine called *Control* in 1965, but what they meant by 'control' was something like open-ended conversation in which each party evolves in relation to the becomings of the other.
15. Like Haraway in her manifesto for cyborgs, Heidegger (1977) runs out of steam at the end of his famous essay. He tells us that enframing is a 'supreme danger' to humanity, but to explain his concept of poiesis he can only look back wistfully to Ancient Greece.

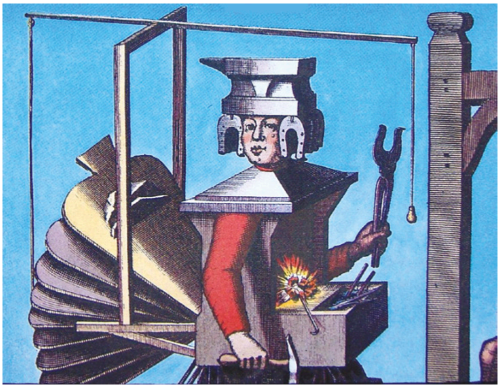
Multi-homeostat set-up and wiring. A picture of a revolutionary concept in machines. This is a machine that accomplishes everything it sets out to do, even if all its determinant factors are upset{disturbed} or reversed. Its aspect is most unpretentious and yet this peculiar faculty of Ashby's machine introduced a complete revolution in our former conception of mechanical possibilities.

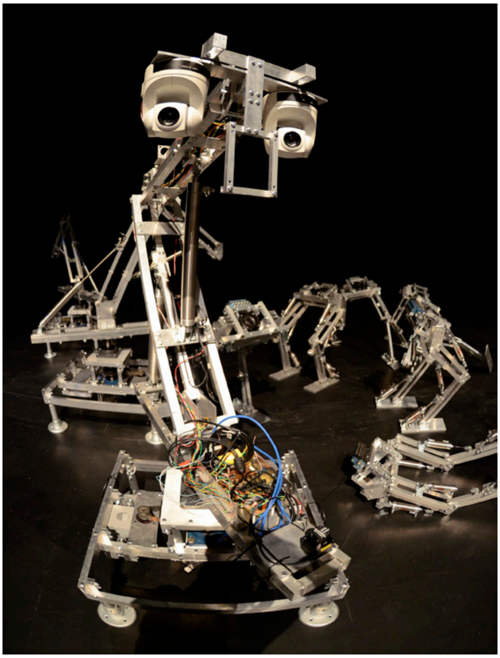


contemporary neo-liberalism. And we should not, therefore, be misled by the critique into tarring all the threads of cybernetics with the same brush; we should not, to switch metaphors, be too quick to throw out the baby with the bathwater. In fact, a symmetric cybernetics is the most radical principled alternative that I can think of to the greyness of neo-liberalism, and my own desperate political hope is that if people grasped and took seriously the neo-Taoist ontology I just sketched out, and lived it, it would denaturalise neo-liberalism and all its works. We could just laugh at our masters' plans for pulling the levers of power – their vision simply does not match how the world is – and then kick them out.[16] Back in the 1960s, Alexander Trocchi spoke of an 'invisible insurrection of a million minds'[17] that would simply outflank the Establishment.

This, then, is the political message I want to draw from the history of cybernetics. Instead of rejecting all things cybernetic as pointing to a logic of control, we could look more carefully and find radical political inspiration in the symmetric cybernetics that has grown from the homeostat. That is the central political point I want to make. But I need to go further. If the critique of cybernetics finds it easy to conjure up real horror-stories drawn from the experience of neo-liberalism, what might count as examples of a symmetric cybernetic politics in action? What would it look like in practice in the real world? In Haraway's second manifesto, *The Companion Species Manifesto* (2003), she sketched out something resembling this symmetric picture as a performative analysis of love, of all things. Perhaps that is enough and nothing more needs be said. This might sound too romantic, but Haraway is not a romantic. Or one could point to anarchist communities, real or imagined, as William Burroughs did in *Cities of the Red Night* (1981), or Thomas Pynchon in *Gravity's Rainbow* (1975), or the Occupy movement. My own strategy is different. It is to descend further into specifics and to document and explore real-world projects that have somehow staged

16. Tiqqun, n.d., pp. 40ff also looks for strategies of escape from their version of cybernetic social control, but in a different direction from cybernetics. They focus on creating panic in a form of guerrilla warfare theorised by Lawrence of Arabia, but now directed at key nodes of the Internet, hoping to cut across a point of social bifurcation as described by Prigogine and Stengers (1984). The emphasis is on resistance and disruption, in effect hoping to shock the social system into some new state on the asymmetric-homeostat model. But the political strategy comes closer to that envisaged here in Tiqqun's repeated references to experimentation, and an undeveloped idea of 'experimenting alongside it [cybernetics], actuating new protocols, redesigning them from scratch and enjoying them' (p. 38). Along the way, they mention 'the celestial Trocchi' (p. 43), and Pickering (forthcoming a) identifies the 'new protocols' of Trocchi's Sigma Project in the early 1960s with the symmetric branch of cybernetics.
17. Trocchi, 1962.





top left – Nicolas de Larmessin II, *Habit de Marêchal*, Paris, ca. 1680, copper-plate engraving from the series *Les costumes grotesques et les metiers (The Fancy Trades Costumes).*

top right – Bill Vorn, *DSM-IV*, prototype for an interactive robotic art installation, also presented at the *Soft Control* exhibition, Maribor, Slovenia, 2012.

bottom right – Stelarc, *Fleshfactor – Informationsmaschine* Mensch, performance, 1997, Ars Electronica, Linz.

a non-modern ontology, and to contrast them with their more familiar modern counterparts as a way of conjuring up a cybernetic politics of practice.

In *The Cybernetic Brain*, I explored in detail a whole range of real-world examples in fields as diverse as brain science, psychiatry, situated robotics, management, education, the arts and entertainment, all the way out to non-standard, mystical and Eastern spiritualities. All of these projects thematise coupled and decentred becomings of people and things. Perhaps the most striking example is the contrast between Ashby's brutally asymmetric psychiatry and the symmetric antipsychiatry of Gregory Bateson, R.D. Laing and others. Antipsychiatry acted out a flat, non-hierarchical ontology of the sane and the mad, in which each was to be transformed in performative and often disturbing interactions with the other, with no pre-assigned telos of normality. R.D. Laing spoke of the mad teaching the sane to go mad. I see a shift from psychiatry to antipsychiatry as exemplary of a practical politics of symmetric cybernetics: exploration instead of normative control; open-ended spirals with no fixed destination rather than closed loops. This is the kind of thing one should have in mind when thinking more generally about cybernetic politics: other ways to be and to act.

Along the same lines, the book also discussed a broad selection of artworks that acted out aspects of the cybernetic ontology, including Brion Gysin's *Dreamachine* (low tech strobes that induce visions), Alvin Lucier's *Music for Solo Performer* (the generation of music from an EEG read-out from Lucier's brain), Gordon Pask's *Musicolour machine* (an inscrutable adaptive machine, to which the human performer had to adapt in turn), and Simon Penny's *Petit Mal* (a mobile robot that lured spectators into literal dances of agency). Like antipsychiatry but in a different register, all of these works help us to grasp aspects of the cybernetic ontology; and they function as existence proofs showing how ontology can make a difference in practice – they are concrete referents in the art world for carrying the politics forward. I want to take this connection to the arts a bit further here by focusing on two new examples that are closely related to one another. Both feature swaying women making mysterious and hieratic gestures that somehow elicit music and connect directly to Haraway's cyborg yearnings.

Real-life cyborgs

The first example is Clara Rockmore playing an analogue electronic instrument dating back to the late 1920s, the theremin, in which the performer's gestures in space generate the sound by modulating a capacitative, performative but immaterial coupling to the instrument.[18] At the end of *Cyborg Manifesto*, Haraway talks about feminist science fiction as a way of trying to put some flesh on her cyborg vision, including a discussion of Anne McCaffrey's novel, *The Ship Who Sang* (1969), in which a disabled woman achieves a sort of completion, with her nervous system wired into the control system of a space-ship – becoming, for Haraway, a politically potent cyborg figure. Without surrendering her autonomy to the same extent, we can easily see Rockmore as a real-world equivalent of McCaffrey's cyborg fiction, Rockmore as absolutely integral and tied into a strongly-coupled, decentred human/electronic assemblage in which neither the human nor the non-human is dispensable, together accomplishing a performance that is beyond either alone. And I would emphasise a further feature of this coupling that is only a subtext in Haraway's writing: its temporally emergent quality. The theremin was not a fixed thing. As Rockmore explained, after she became fascinated by an early version, Leon Theremin developed the instrument further in response to her suggestions, and these suggestions themselves evolved in relation to Rockmore's increasing familiarity and experimentation with the instrument. So the experimental becomings of Rockmore, the instrument and the sound exemplify and stage for us, in the real world, not only a cyborg coupling of people and things, but also one of those performative, productive and transformative dances of agency, an open-ended spiral with no fixed future destination. The history of Rockmore and the instrument thus plays out for us, in the real world, the sort of open-ended performative experimentation and unpredictable becoming that hangs together with the cybernetic ontology.

The second example is Julie Wilson-Bokowiec in a 2012 performance called *V'Oct(Ritual)*. Again the hieratic gestures somehow control the sound, but now the technology is different.[19] Switches and sensors on the performer's hands and arms control a complex digital environment called *Bodycoder*, shifting intensities and frequencies, controlling loops and delays, all ultimately deriving from Wilson-Bokowiec's voice as input.[20] Like Rockmore, Julie Wilson-Bokowiec emphasises that the technology of *Bodycoder* does not exist independently of her performance, but has itself evolved in accompaniment with her growing expertise in and her explorations of earlier versions – another open-ended, decentred and emergent dance of agency.[21] And she notes that this is also true in real-time: 'there is a kind of live negotiation that goes on between the acoustic

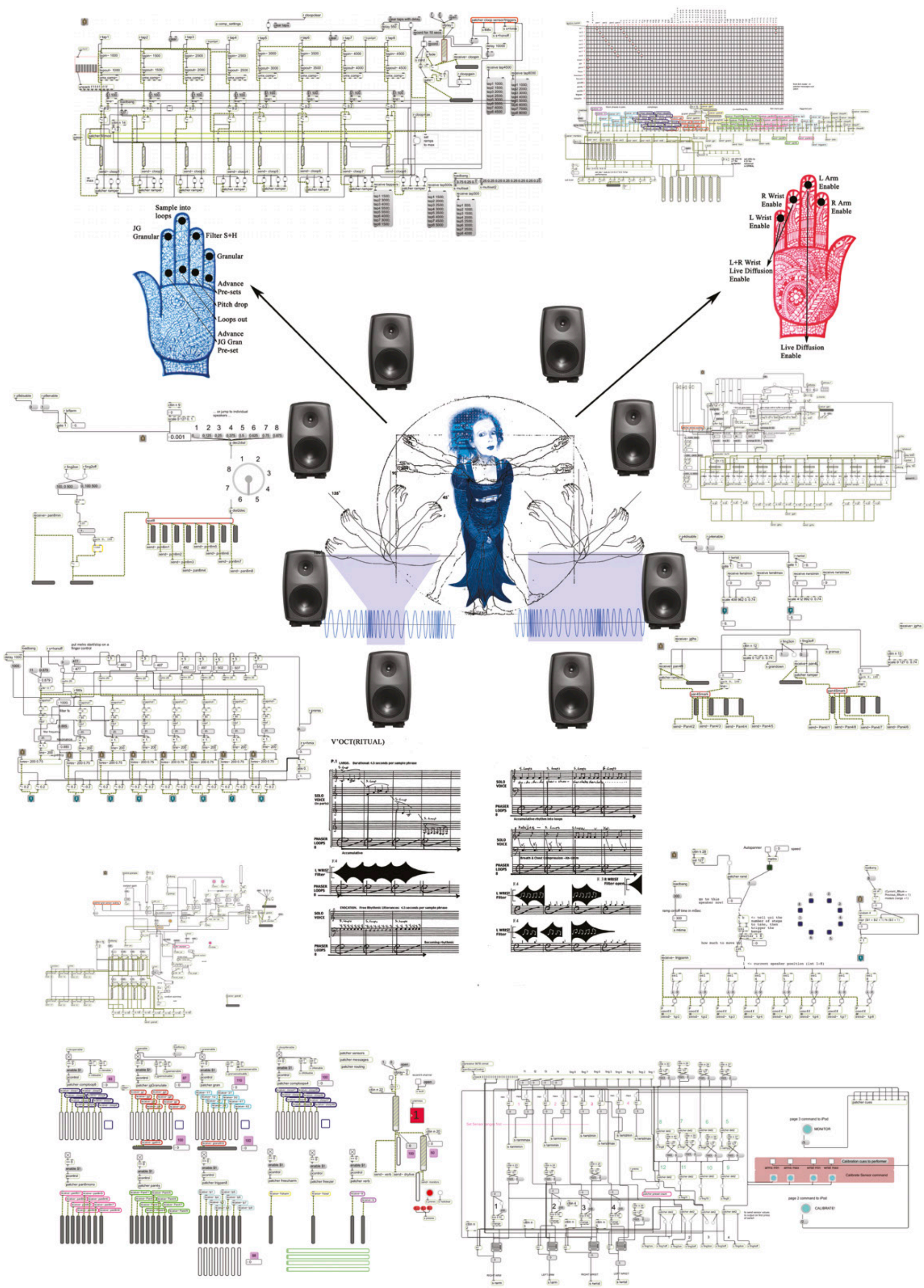
18. Many videos of Rockmore performing are available on YouTube, for example www.youtube.com/watch?v=9FLdHV9DZjM&list=PLCE50D19E676E20DD.

19. For videos and further sources see www.bodycoderblog.blogspot.de.
20. Bokowiec, 2012.
21. Wilson-Bokowiec, 2012, pp. 87–88.

top – Clara Rockmore (1911–98) was one of the world's most accomplished theremin performers.

bottom – Theremin soloist Lucie Bigelow Rosen (1890–1968) is remembered for popularising the use of the instrument in the 1930s and 1940s.

V'Oct(Ritual) schematic by Julie Wilson-Bokowiec and Mark Bokowiec.



voice and the processed... I sometimes have to listen more intently to the electroacoustic consequences than I do to my own acoustic vocalisation'.[22] Each performance of *V'Oct(Ritual)* has, then, the same quality of an emergent open-ended back and forth between the human and nonhuman.

So we could think of theremin and *Bodycoder* performances as the accomplishments of real-life cyborgs, acting out the cybernetic ontology of decentred explorations and becomings in the real world, showing how the trick can be reproduced in the arts, how to live it and what it can look like. In this sense, theremins and *Bodycoders* would be a further punctuation of the trajectory of cybernetic machines, moving beyond the concern with stability that characterised the homeostat in favour of performative experimentation and emergence. The theremin/Clara Rockmore couple or *Bodycoder*/Julie Wilson-Bokowiec could be our icons for a politically promising cybernetics, staging new and emergent practices, new ways to go on, new worlds and new civilisations, here in the arts.

Strange performances and dark arts

In her writings, Wilson-Bokowiec assimilates *Bodycoder* and the *V'Oct(Ritual)* to a novel category of 'digital opera' and her text then moves to explorations of the human voice and techniques that have helped extend its range amazingly, with individual singers covering extraordinary intervals of up to eight octaves.[23] Here we are in the realm of what I call 'strange performances'[24] – human capacities beyond what is usually considered normal or even possible, more often associated with Eastern yogis than Western musicians or singers. Wilson-Bokowiec also points out that these techniques typically involve working both on the voice and on the psyche of the performer, often along Jungian lines, thus underlining a connection between the outer and the inner, between strange performances and altered states – emergent subject-positions and selves. Elsewhere, she describes a new physical sensation of 'grainy resistance' that emerged, in the absence of any physical input, alongside 'moments of acute physical and aural focus that required difficult finite control' in working with *Bodycoder*.[25] And this highlights a further important aspect of the cybernetic dark universe, namely that we are part of it, not only as performative agents but as ourselves unknowable,

22. Bokowiec, 2012, p. 7.
23. Bokowiec, 2012.
24. Pickering, 2010.
25. Wilson-Bokowiec and Bokowiec, 2008, p. 135.

about which there is always something new and surprising to find out. This was also the spirit of the antipsychiatry movement and, of course, counter-cultural ‘explorations of consciousness’. Realising and acting out the fact that we ourselves are not fixed entities is a key element of a neo-cybernetic politics, denaturalising the tamed and domesticated modern subject that underpins neo-liberal control strategies.[26]

After the dark universe and dark matter, we could think about the dark arts: magic. References to magic have always stalked the cyborg; the Golem of Prague and the sorcerer’s apprentice are all over early cybernetics literature. And the Bokowiec’s are right to call their work *V’Oct(Ritual)*. Julie Wilson-Bokowiec’s performance looks like nothing so much as magical incantations and gestures.[27] Somehow she conjures up strange sounds from thin air. Haraway, I suspect, is too modern for magic to figure seriously in her manifestos.[28] But this magical quality serves as a reminder of how drastic the cybernetic shift away from the modern sciences is, and the extent to which it opens or re-opens spaces for rethinking and re-enacting the dark universe.

26. Wilson-Bokowiec (2012, p. 88) emphasises how much she herself has changed mentally and physically in her association with *Bodycoder*: ‘My own performance abilities have developed to include a range of technical, perceptual and aural skills. These are specifically digital crafts as opposed to stage crafts, associated with utility and expressive operations within the system, as well as the cross-modal sense perception and articulation of sound’. And ‘My larynx and mouth know how to do this; it exists within their deep muscle memory. I am thankful because it is often the case that I cannot hear my acoustic voice in the midst of the sonic density of performance. Articulation in this respect relies on establishing a meta-score: a sensual physicality and kinaesthetic knowledge of a work that is fixed in rehearsal’. Gordon Pask argued that engaging an unknown system in conversation entails establishing an appropriate language (Pickering, 2010), and it is interesting to note that Wilson-Bokowiec (2012, p. 88) does something similar in relation to *Bodycoder*: ‘I sometimes memorize the shape and progression of an abstract vocal phrase by characterizing it in some way or by attaching a kind of dramatic intention to it, sometimes as mood, memory or emotion… For example… I characterize this phrase sequence as ‘whale’ – or more precisely whale song. The idea of the whale helps me to articulate the patterns of the phrasing’.
27. ‘The word diva has very ancient roots… in plurality, the metaphysical and the divine… it often denotes an entity with the ability to be both male and female… and possessing the skill to appear in trans-human forms: animal, mineral and vegetable. As a transgendered and transhuman entity its qualities are dynamic and transcend human law and authority. Re-imagining future opera divas endowed with something of the ancient qualities… seems an inviting and interesting prospect’. (Wilson-Bokowiec 2012, p. 83).
28. See Pickering (2009) for a discussion of Latour’s modernity. Many people want to draw a modernist line here. In the arts, Suzanne Treister’s *HEXEN 2.0* project addresses what she sees as the political ambiguity of cybernetics via a set of cards that conjure up key individuals and projects in its history. But despite her overt gestures towards witchcraft and Tarot she suppresses the active interest in non-modern spiritualites that runs through the history of cybernetics (www.sciencemuseum.org.uk; www.blackdogonline.com; for a review, see Pickering 2012).

David Woodard and William S. Burroughs standing in front of the *Dreamachine* in Lawrence, Kansas.

Acting out an ontology of unknowability

I have done my best to locate the fascination for cybernetics in its ontology of unknowability, and to sort out vectors of political critique and promise by referring to a sequence of machines: thermostats, homeostats, theremins and *Bodycoders*. I can conclude with two remarks. First, I said earlier that neo-liberalism probably owes very little to technical developments in cybernetics, and I should say the same about the examples I just discussed. The theremin predated cybernetics; Julie Wilson-Bokowiec didn't read Haraway until the *Bodycoder* project was well advanced.[29] So what role does the discussion of cybernetics play here? It functions as an axis of political assembly.[30] Though resemblances between the theremin and *Bodycoder* might be obvious, only by reverting to ontology can one associate both with, say, Gysin's *Dreamachine* and Pask's *Musicolour*, and all of those with the other projects I discussed in *Cybernetic Brain*, in robotics and management, and so on. The ontological reading creates what I think of as a practical gestalt – a gestalt of practices – in which apparently disparate elements (bodies, projects and artefacts) appear as part of a unified whole, a non-modern paradigm. I don't think that individual elements of the paradigm like *V'Oct(Ritual)* will ever be enough to trouble the society of control, but maybe a big enough assemblage could – denaturalising it by staging a much more attractive alternative. My own political contribution, then, is this act of assembly via the trip through ontology.

Why have I focused here on art? The answer is that artists have taken the lead in exploring symmetric versions of the cybernetic ontology in very imaginative ways, so we should pay attention to their achievements. But art is not enough. The political move must be to understand neo-cybernetic art as ontological theatre, as helping us to grasp an ontology of unknowability much more generally by staging it before our eyes and showing us that it can be acted out, not just in art but, more importantly, in all the other practices and projects the cyberneticians started to open up – in psychiatry, biological computing, environmental management, whatever.[31] This, for me, is the central role of cybernetic art in producing another world, as an avant-garde not so much in art but in an ontological politics of real-world practices.

29. E-mail, 7 December 2012.
30. Pickering, forthcoming a.
31. Pickering, forthcoming b.

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THE GHOST IN THE SOUND

Interview with CM von Hausswolff

Peter Bruyn

Since the 1970s, one of the themes in the work of sound and visual artist Carl Michael von Hausswolff is to make electricity – energy – audible or visible. Another one is based on an artistic fascination with so-called Electronic Voice Phenomena (EVP). Apart from these, Von Hausswolff works has worked for several decades with Swedish artist Leif Elggren on a conceptual art project called *The Kingdoms of Elgaland-Vargaland (KREV)*, a nation consisting of all those 'in-between' pieces of land. *KREV* is the no-man's land between national borders, but also between digital and mental spaces. *KREV* has its own national anthem, flag, currency and even citizens and administration. CM von Hausswolff has released dozens of records and CDs. Noteworthy are the extremely minimal *Ström* (2001) and the more recent *800.000 Seconds in Harar* (2011), based on field recordings made in Harar, Ethiopia, where Arthur Rimbaud lived towards the end of his life, and on works by this French poet. At Sonic Acts 2013 Von Hausswolff presented the ninth edition of *freq_out*, a collective work by twelve sound artists that he initiated in 2003. The sonic spectrum from 0 to 11,000 Hz is divided into twelve frequency ranges. Each participant composes an individual sound piece within one of the ranges. When combined, the twelve works make up the *freq-out* installation. Participants in *freq_out #9* at the Stedelijk Museum Amsterdam were Mike Harding, Jacob Kierkegaard, PerMagnus Lindborg, BJ Nilsen, Petteri Nisunen & Tommi Grönlund, Finnbogi Petursson, Franz Pomassl, Christine Ödlund, Kent Tankred, JG Thirlwell, Maia Urstad, and Jana Winderen. Peter Bruyn interviewed Von Hausswolff at the Stedelijk Museum, during the setting up of *freq_out #9*.

Peter Bruyn *Freq-out* as a sound work in an architectural space is sometimes associated with the Philips Pavilion at the World Expo in Brussels in 1958. Was that an inspiration for you?

Carl Michael von Hausswolff It isn't the only inspiration. I was only two years old when the World Expo happened. But when I first heard of the Philips Pavilion I thought that it was a wonderful thing that people from varying disciplines could actually do something together. It could be seen as a forerunner to a collaborative work like *freq-out* where sound is very much connected to architecture itself. Xenakis actually did most of the work for the pavilion. He designed it and also composed the first phase of the music, although it was Varèse who completed the music. But the wholeness of that project is very much what *freq_out* is about too.

PB There are always twelve participants involved in *freq_out*. Is it a fixed group?

CMH The rule is that if someone cannot make it, I invite someone else. It wasn't planned like this from the start, though. At the very first *freq-out* in Copenhagen, we all felt that it was very interesting to work together. So when we were invited to do a second one in Oslo, it was more or less a demand from the participants that we all come together again. All of us experienced it like a tight group, almost like a band or an orchestra. So then I decided that when somebody couldn't make it, I would invite a new member, who also stays for the next *freq_outs*. And that has happened twice so far. But everything is open to change as well. I'm not dogmatic in that sense.

PB The concept is based on twelve different frequency ranges. Does everyone work with the same frequency range each time?

CMH No, it changes. Each person is assigned a new range of frequencies each time we perform *freq-out*. That's why we will only do twelve *freq_outs*. But that's not definite either. Maybe something new comes up that will develop *freq_out*. It's not fixed.

PB Is each of those frequency-ranges as interesting as the others for each participant?

CMH From a theoretical point of view I'd say 'yes'. But from a personal point of view, maybe it's not. Some artists might be more interested in low frequencies and some in the high pitches. But in these cases they just have to accept their bit, the frequency they get in the installation. This project is very much about acceptance. And about generosity as well. It's also a social project.

PB It's interesting that you call it a social project, because two large ensembles or groups come to mind immediately that also have been called social projects or social experiments: Keith Rowe's MIMEO and Peter Brötzmann's Chicago Tentet.

CMH I often compare *freq_out* to free jazz, because of the music's structure and because the musicians have to accept each other's musical choices. In *freq_out* everyone has to accept what the others are doing. It's not a collaborative work. Everyone works individually, each with their own eccentricities. They have to accept what the others are doing because of the structure of the set-up. It's very much like a free jazz group.

PB And more technically, are all the frequency ranges as difficult or as easy to work with as the others?

CMH I think the high and low frequencies are a little bit more difficult to work with, because of the variation. It's not so easy to work with variations when you have frequencies

freq_out #9, sound installation, 2013,
Stedelijk Museum Amsterdam, Sonic Acts
The Dark Universe festival opening, 2013.

freq_out #9, Stedelijk Museum Amsterdam,
installation set-up, 2013.

between 15 and 25 Hz. That's quite low if you want to work with pulses or sine wave interference. And the same for high-pitched frequencies up to 11,000 Hz. But that can also be a challenging study, of course. The most used frequencies are those we hear on the radio and so on, which are very much midrange.

PB In interviews you related *freq_out* to Deleuze's ideas about the 'rhizome'?

CMH I think *freq_out* is a very good example of Deleuze's idea of rhizome. *freq_out* doesn't have a beginning and it doesn't have an end. It just has a 'stem'. And then the branches can grow out of this stem. It doesn't have a top or roots, like a tree. There is no beginning or an end. And each branch can become a new stem again. But this is nothing new in music. You have it in meditation music from India and Tibet as well, in drone music in general. But it is in its approach to collaboration that *freq_out* is different.

PB Do you see yourself as a sound artist or a composer?

CMH I usually say 'artist', because I work in many different disciplines. I work visually, I work with audio, I work conceptually. I think I would be limiting myself with a label. Sometimes, when I come to a totally different subculture where, maybe, they have never heard about installations or conceptual art, I say I that I'm a composer of electronic music. Everybody understands that. So it depends very much on the environment I'm in.

PB Your CV on the Touch website doesn't mention how you started as an artist. Did you start by working with sound or with visuals?

CMH I started with sound. In the small town in Sweden where I grew up, there wasn't much visual art, there weren't any art museums or galleries. But there were really good record stores with a wide variety of popular and especially avant-garde music. So it started mostly with music. Sounds.

PB What were the first things you made yourself?

CMH The first things I did were more like sound-installations. I developed sounds that weren't really played by instruments, because I didn't want to learn an instrument. I'm quite lazy and I thought why should I learn to play an instrument when other people can play them so well? I wanted to develop my own way of doing music. Playing my own sounds, playing in my own language, so to speak. And to make music without any references to anything else. I worked a lot with electronic sounds, but also with the environment – I used field recordings, and body sounds. These sounds were used in installations and environments in old buildings and so on.

PB In your CV you mention three periods in your artistic development. First, from 1979 to 1992, you composed drones from a mainly aesthetic approach. After that you were more interested in the sound of electricity – the raw and pure sound of energy. Was that change based on a theoretical concept, or were you bored with making 'nice' sounds?

CMH It was more a process of peeling off ornaments from the music and the sounds – to get to more pure sounds. To see if those more single or 'lonely' sounds could also be called music. At the same time I became interested in what pure sine waves or sounds really represented. Do different frequencies actually represent something like an image? Music is much more abstract than visual art. But nevertheless I was very interested in finding some kind of interpretation. What does it really mean? Then I found out that it could very much be connected to my body: my brain, my chest, my heart, my sex, my legs and so on. Not that this was evident from the records I produced. But from a personal point of view I was very interested in these aspects.

PB You say that music is more abstract than visual arts. At the same time you often hear from people that music affects the emotions stronger than visuals. So when you remove the ornamental aspects of sounds, do they still influence the emotions in the same way? Was that also one of the things you wanted to research?

CMH Yeah. Emotions are connected to the nervous system. Of course it depends on the kind of emotions. Are we talking about conventional feelings like love or sorrow? Then I think visuals can be equally emotional as sound. Sometimes visuals influence those types of feelings even more. But there are also feelings where you don't know exactly what you're actually experiencing. You feel a physical sensation without knowing what it is. That's what I was interested in, and still, when I play live solo, with a good PA-system, I can investigate this. I am interested in the properties of how sound works in an architectural environment, with people present. And how combinations of sounds can move people, or at least physically touch them, without them being aware it's happening.

PB Is there a theoretical development parallel to your work, or is it all intuition from the beginning?

CMH I tend to avoid personal theories about these things, because I am too afraid to lock myself up in a dogma. But I'm very fond of looking back at my earliest work and trying to figure out why I made it, and what the progress was. But I have that experience now and I rely very much on it. My intuition together with my experience fills me with joy. Even if I work in a kind of melancholic way, I still feel that joy. I don't believe in providence or predestination. I never sail on totally unknown waters. Not that I am afraid to fail. Failure is very important.

PB How do you look back on your earliest works? Do you recognise them now as 'early works' or could you have made them yesterday?

CMH Of course there are pieces that I would do differently now. But at the same time there are pieces that continue to fascinate me. It has to do with how I see myself, my own person. The last record I did has several photographs of me on the cover, of me as a baby, some as a boy, and some of me as a grown-up. When I look at those pictures I see the differences, of course. But when I look at them again I see that they're all exactly the same person. I'm older and more experienced. I've done more things, travelled to many countries. I know more languages. But apart from that I'm exactly the same. That fascinates me. And so I can also look at that older work as having been made by exactly the same person, who is more experienced now. That's very positive, I think.

PB Regardless of how abstract your sound work is, it is about yourself?

CMH Yes. Although a lot of people say 'You never make work about yourself'. But when I look at it, the only person that could have made it is me. And it is about me. But it transforms me as well. Things are connected. Just like *freq_out*: Things are connected. You don't live alone in the world. We are all connected parts.

PB Your music is about drones, combinations of frequencies, and frequencies combined with volume. How important is volume in your work?

CMH Of course volume is important, but dynamics are much more important. I'm not into loudness. My pieces are usually not painfully loud. I'm interested in the relationship of sound and architecture. A room's acoustics. You don't need so much volume to work the dynamics.

PB Is the scientific relationship between frequencies and the dimensions of a room important for you?

CMH It is not something I actually studied. But the relationship certainly exists otherwise we wouldn't have churches and cathedrals with fantastic acoustics. It's an old profession, although these theories seem to be applied less and less in contemporary architecture.

PB When you're in a room for a concert, do you know what frequency to use in that space? Or do you go through the spectrum in a hit-and-miss way?

CMH I calibrate the sound with the space. It has a lot to do with working with the space instead of against it. From a scientific point of view, when you build a concert hall, you take a lot of measurements, just to design it so that the sound is good. With *freq_out* we take it the other way. We say that every space is a good space. We take the sound to the space, and then we work with the space, using those frequencies that we know the space is actually corresponding to.

PB Your album *Ström* is one of your most minimal recordings. What was the concept behind it?

CMH I'd done some audiovisual installations where I took the image and the sound of the electricity from power sockets in Paris, Stockholm, Bangkok, wherever I was. I suggested that when you see the oscillation projected on the wall, you see and hear the sound of electricity. Then, I suggested, maybe you can detect ghosts that live in the electrical system. That was the concept. A sort of electronic séance. So what you hear on that record is actually the 50 Hertz current in Stockholm. And then I mixed the sound of several of those installations I did around the world into those recordings.

PB *Ström* reminded me immediately of La Monte Young's *Dream House*, which was based on a completely different concept, but sounds about the same.

CMH Indeed, the attitude is very different. Mine was pseudoscientific. His attitude was more… er… 'astral'. The common thing could be that his piece is about spirituality, while mine is about spirits...

PB You also research so-called Electronic Voice Phenomena. How serious is that? Is there an aspect of humour in it, or is it all a deadly serious?

CMH There must always be a humorous aspect, even if what you do is deadly serious. Art without humour doesn't really work for me. When I started investigating EVP, it wasn't to prove anything. I'm not a scientist. I wanted to show possibilities. Possibilities of life forms in electric circuits. I use radar technology and sonar technology in these installations. But once I started doing them I got in touch with people who do proper EVP research. And I found it quite interesting to collaborate with Michael Esposito from Chicago, who is an EVP researcher. I combine my more or less art approach with his research, and see what we can do together in terms of formatting; or in terms of displaying it in another way than the standard EVP. So in that sense it is very serious. For me it's about energies, not so much about ghosts walking around. It's very much about energy forms and traces of energy from past times. Can some trace of an event be – energy-wise – left in a place? Michael Esposito said it once very nicely and I usually quote him on that: 'If you come into a room and people have been quarrelling there, a very heavy quarrel, you feel that'. You feel that something had been going on there. Maybe it's the smell of sweat. Maybe you feel that the room is a bit warmer. But there is also something else. You just don't feel comfortable. You feel that something is still there, lingering after the quarrel. You have to open a door or a window to let the air circulate a bit or something like that.

PB Your drone work is often compared to that of people like Zbigniew Karkowski, Merzbow, Sachiko M and Francisco López. Listeners who aren't deeply into their output often find their works hard to distinguish from each other, despite their approaches being different. Do you see all of them as different, or do you feel that they have something in common?

CMH That question is a bit difficult to answer, because I know them, some of them are friends of mine. They all have different temperaments and I have mine. Their personalities and temperaments are reflected in their work. There is one difference I can think of: I don't have much affinity with pieces that are totally unexplained. I always give some kind of clue as to what my records are about. Not long texts; it can be in titles or as a few sentences on the cover. *Ström* is the exception, by the way. I asked the label Raster Noton to publish a few lines of text on their website, but they didn't. So when it's released again, that text will be on the cover. But I never see such texts on records by Karkowski or López. They have a different attitude in that respect.

PB Do you think that most people are aware of drones as music, and using them consciously?

CMH I think people sometimes use drones without knowing. We live in a world that has a constant drone. Everything has frequencies and so does the Earth. It's a very low frequency, but we live in it all the same. We live surrounded by energies, regardless of whether we can detect them and know what they are, or not. And that is what drones are about as well. Maybe drones try to tell us that. Drones aren't something new. You have mantras from India, and throat singers from Mongolia. The sounds produced by Aeolian harps are drones as well. Even a composer like Gustav Mahler was very much interested in them. If you think of the world as a complex of energies, or energy fields, and you look for explanations, then you'll realise that drones are quite representative of those kinds of energies.

PB I've seen you play in rock clubs for a standing audience, in museums and art spaces for seated audiences, in an art lounge where everybody was drinking and talking and nobody listened. Is there a perfect audience or place to perform your music?

CMH I think every place is an interesting place. I can play in bars too if I have a loud enough sound system. First I hear the audience talking and then I don't hear them anymore – and they don't hear each other anymore either. They don't hear what they're saying to each other because I calibrate the sound with the place so well that they can't talk. It is very interesting that this can be done. I'm very aware of what is going on. I am a very 'listening' person when I play. I don't play theoretically; I play actively. My ideal spaces are spaces that I have never performed in.

PB You did two projects with the curious titles *The Thinner & Low Frequency Bar* and the *Glue (Tobacco) & High Frequency Lounge*. What kind of projects were those?

CMH It's a series of social sculptural projects that I do, based on creating a space where you can actually have a drink. I was interested in the hypocrisy of drugs policy, which outlaws marihuana, but allows you to go into a shop and buy thinners. I created a sonic environment for those bars. So I thought, what kind of frequency do I associate with thinners? And the same with glue, which seemed to have a much higher frequency than thinners. Those pieces have to do with social criticism.

PB How does this relate to the project, *The Kingdoms of Elgaland & Vargaland*?

CMH The project *The Kingdoms of Elgaland & Vargaland* has to do with how we view our lives. Do we really want to be a part of a certain type of hierarchy? Why do we have a king in Sweden? Anybody could be a king. It's about the nation state. Has it any function now? What is a nation state nowadays? We think that it's something that has lost its significance. Like religion, countries and states seem so old-fashioned and such manipulative concepts. They're so power-hungry. They're just there to oppress people, to make money for those in power. *Elgaland & Vargaland* is a criticism against these kinds of systems. It's a very serious project but at the same time it's two artists – Leif Elggren and me – who still play cowboys and Indians. It is like a kid's game, and at the same time it is a very, very serious game. It is still going on; it will never end.

PB In December 2012 an exhibition of your work in the Martin Bryder Gallery in Lund, Sweden, caused a riot because you were said to have used ashes of victims from a Nazi concentration camp in Poland in one of the paintings. What exactly did you do?

CMH It was just another way of working with energy. To go to a place where something happened; to make a recording there, in that very space, analyse it, see if there are any electronic voices, any voices from the 'other side' or whatever. The paintings were more like a visual alternative to those sound works, to see if there was any energy left in the material I used – which was dead material. It was an experiment. And of course, sometimes sadly, that upset a lot of people, especially Jewish fundamentalists.

PB Apparently you stole some ash...

CMH That's what I've been accused of and in Poland they would have prosecuted me if I'd done it. It's not something I've said; it comes from the viral effect of journalism and newspapers nowadays. They repeat what somebody else said. It's like Chinese whispers. The Polish newspapers wrote that I'd stolen some ash, but they have no evidence of this. And I say that I haven't stolen anything. If I had, it couldn't be proved anyway, because DNA analysis doesn't work with ash. Maybe they were put under pressure by the Jewish community; they have accused me of murdering Jews again – the same people who were murdered in the camps. I'm not answering any questions from the press about this, because I'm still threatened by prosecution in Poland, so I always have to check with a lawyer to find out what is going on. But generally those works have the same approach I always use: looking at energies in all their different forms and seeing if they have anything to say.

FRAY

Raviv Ganchrow

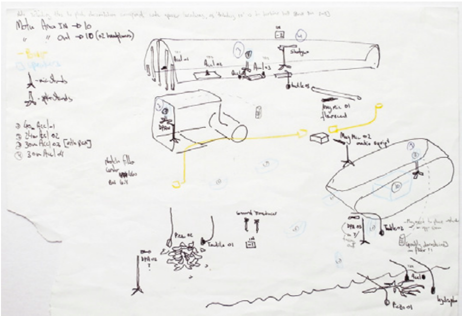
Fray is a site-specific sound intervention that reworks the immediate acoustic environment of a roadway tunnel and probes the relations between sonic ambience and a sense of surroundings. The installation is situated in an infrastructural access branch to the tunnel underneath the Austrian village of Dürnstein, adjacent to the banks of the Danube. The site includes a ground level chamber, a series of upper level galleries and a maintenance viaduct. *Fray* investigates the unnoticed *seams* in audible coherence – a coherence that is in many ways conducive of perceptions of our everyday surroundings – with particular attention to instances where the stitching noticeably *loosens*.

SIGNALLING SURROUNDINGS

The environment conducts signals without intended messages. Perception completes a circuit with environmental conductivity.

How do oscillations shape surroundings and how do surroundings transform the vibrational continuity? In order to appreciate the complexities of ambience one must draw attention to the manners in which surroundings synthesise themselves vibrationally. The reflective and refractive shaping capacities of the environment amplify, attenuate, filter and diffract sound [1]. To hear aspects of environmental sound synthesis, just lend an ear to the amplitude modulation of distant sounds caused by slight atmospheric variations. Listen to the slow pitch shift of a aircraft passing overhead at 32,000 feet, or the granular pulsations of pebbles underfoot. Considering impressions of surroundings in terms of their transductive capacities also suggests a form of environmental conductivity [2]. The material environment is a conduit as well as a soundboard for oscillations. Attention itself closes circuits with environmental capacitance [3], and it is into this ecology of tensions, with its charged

[1] The specific curvature and physical properties of Dürnstein lower gallery tunnel acoustically trap and amplify motor drones of barges straining against the upstream current. Vaulted chambers inside the upper chambers of the tunnel have a similar effect on automobile engine sounds. In *Fray* the entire network of chambers was conceived as an enormous loudspeaker with the midrange and high frequencies concentrated on the lower level of the installation, and the bass and distant filtered vibrations in the upper tunnel tributaries.



[2] The third terminal in household electrical outlets takes its name, 'ground' or 'earth', from the mid-nineteenth-century discovery that the soil can be employed as the return path of electrical circuits. In certain telegraph and power transmission circuits the ground itself is used as a conductor for the circuit. Today, long-wave radio transmissions still exploit surface conductivity, as well as differences in the refractive index between the earth and the atmosphere, to send 'surface waves' that creep along the curvature of the earth. These wave propagations achieve radio coverage well beyond the horizon. Buried floodlight cables on the banks of the Danube saturate the ground – itself a conductor – with a faint current alternating at audible rate. Two rods inserted into the ground, with the soil closing the circuit, are enough to pick up electromagnetic fluctuations.

[3] 'Reflective perception is a circuit, in which all the elements, including the perceived object itself, hold each other in a state of mutual tension as in an electrical *circuit,* so that no disturbance starting from the object can stop on its way and remain in the depths of the mind: it must always find its way back to the object from where it proceeds.' (Henri Bergson, *Matter and Memory,* trans. Nancy Margaret Paul and W. Scott Palmer, London: George Allen and Unwin, 1911, p. 127.)

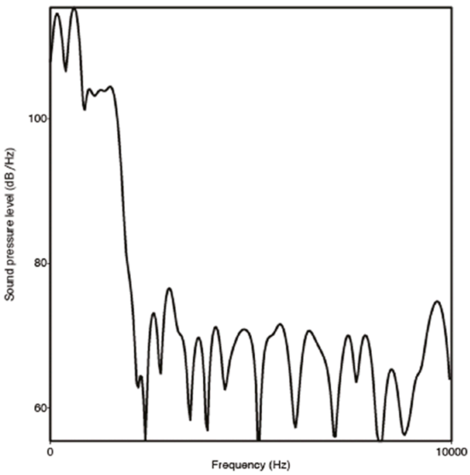
[4] It is through an ongoing contact with the diversity of everyday sounds that an absent-minded attention takes hold, preparing unconscious modes of listening. Once induced, such *modes of listening* then resurface elsewhere in the social praxis, shaping (often contradictory) meanings in for instance art, industry, history and political legislation. To comprehend this complex conditioning of auditory attention we must not only

The built environment is an auditory technology. Electronic and mechanical sounds in our everyday surrounings create an absent-minded attention fostering unconscious modes of listening.

notions of hearing, that audio technologies subsequently discharge. Plugging-in anywhere in the material universe, given the proper amplification methods, inevitably yields a signal, though peculiar ones may defy the very definition of 'signal'. These are signals that somehow bypass communication models of sound transmission. They arrive at the receiver with no intended messages in hand, yet provide unexpected entries towards alternative perceptions of sound. Furthermore, the implementation of widespread communication and electrical networks reveals another form of environmental transduction. Channelled back into the surroundings via cables, conduits and antennas, our everyday surroundings have become thoroughly wired for sound. Naturalisation of the loudspeaker and other sounding devices, over the course of the past century and its incorporation into anatomies of public space, transportation, and nearly every aspect

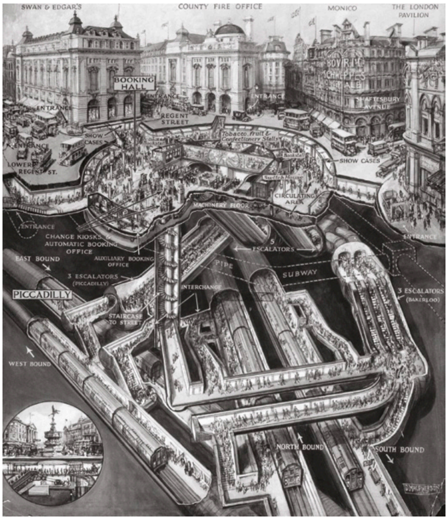
consider sound making devices, but importantly consider architecture, and by extension urban space and other containers of everyday life in general, as constituting unintentional, yet formative, auditory technologies.

[5] Vehicle back-up alarm signals, aside from their practical function, also provide a sonar-like registration of the acoustic surroundings as much as they invest the beeping with particular timbral-spatial signatures. During the research phase of the project a rotunda foyer to a housing complex in Krems was explored for its acoustic properties when a truck idling in a nearby alley activated a modal resonance that set the space into drum-like undulations peaking at around 31 Hz.

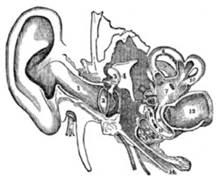


[6] In signal processing, a Transfer Function is a mathematical function relating the response or output of a system (such as a filter characteristic) to an input stimulus. Every material has its own unique resonance pattern that, when activated by broadband vibrations or by impact, exposes their patterns in terms of emitted partials and overtone structures of spatial vibrations.

[7] The anthropomorphic reflex that finds the body back in observed surroundings is apparent in histories of depiction, and landscape painting in particular. More recently modern images of the dissected anatomical body created parallels between infrastructures of flesh and metabolisms of the urban environment. By the late nineteenth century New York's infrastructure was thoroughly networked, extending well below street level, and consisted of passageways and subways, drains, gas mains and electrical power channels. Cutaway drawings such as the one from *The New York Tunnel Extension of the Pennsylvania Railroad,* ca. 1910, show a striking resemblance to sectional anatomical drawings of flesh.



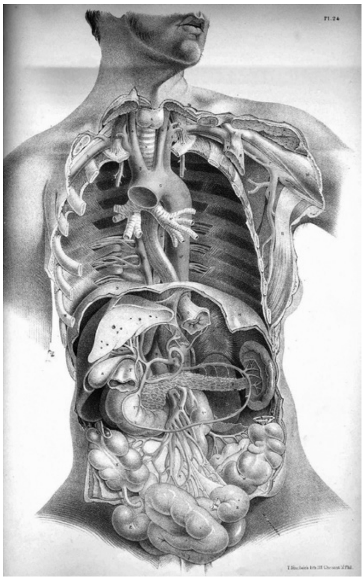
The idea of city as organism is implicit in urbanism where architectural terrain is deemed 'tissue' and planning is understood as 'remedy'. Plumbing the city with various arteries that 'transport' draws inevitable parallels with bodily infrastructures, exemplified in Douglas MacPherson's 1928 cutaway illustration of Piccadilly Circus dubbed *The Stomach.* Contemporary accounts of sound have colonised these urban infrastructures with an expansive cacophony, mining sonic geographies where sounds metabolise into imagined infrasonic rhythms or fuse into eternal polyphonic drones.



of the domestic sphere, creates a kind of absent-minded attention to the specific sonic registers of such devices [4]. We have become accustomed to hearing these electrified sounds in combination with a variety of spatial acoustics such that the one becomes the measure for the other and visa versa [5].

Hearing an 'environment' implies combining specific notions of sound with distinctive theories of landscape.

To imagine the material environment in terms of complex transfer functions recalls another environment that transports vibrations, namely that of the ear [6]. In the ear vibrations convert from voluminous waves to surface undulations to mechanical oscillations, into aquatic sloshing, whereupon they are literally transduced into electrical pulsations. This nesting of environments (or ears within an ears) may be one reason why we keep finding ourselves back in the surroundings to which we pay attention [7]. To tune into the fuller spectrum of oscillations necessarily means giving up biases invested in our physiological limitations as well



Space is a secondary, emergent, quality of sound and localisation is only one instance in a much broader spectrum of sono-spatialities.

as undoing some of the environmental nesting in order to reveal a more primary field of interactions. In other words: make room for all those vibrations that are too slow, too fast, too complex or too diffuse for our limited frames of attention and perception. In such a broadband sense of vibrations, we could explore non-anthropocentric, or even inorganic, notions of hearing. [8]

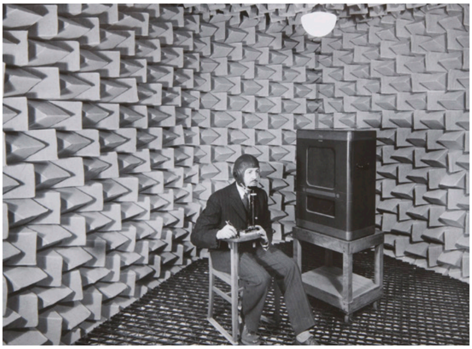
AUDITORY SITUATEDNESS

Sound always seems situated *somewhere*. Even in the case of deep bass tones, sound comes from everywhere, but never from nowhere. Furthermore, the apparent 'where-ness' of sound is always in relation to an observer's vantage point or listening position. The expansiveness of sound is not merely a matter of localisations [9]. In fact the only reason we hear a sound in the first place is because the travelling vibrations have thoroughly escaped their source [10]. Nonetheless, we seem to have got into the habit of pointing towards the location of its imagined emissions. Strictly speaking there never can be a geometric 'point' from which

[8] Unrelated yet intertwined tributaries of vibratory activity contribute to the sound world of *Fray.* The installations taps into the sound of cars; the resonance of tunnels; vibrations in the concrete from which the tunnel is made; the buzz of the light fixtures and outdoor buried power mains; wind sounds and rubbing of branches; as well as the friction of shifting water levels in the Danube. Likewise the installation listens to its own listening apparatus by incorporating the sounds of microphone membranes themselves, rattles from the sub-woofer grating, feedback and other artefacts of amplification as well as the omnipresent 50 Hz hum seeping into the countless metres of cabling.

[9] Localisation, a particularly recent mode of sonic attention, came to prominence with developments in mechanised warfare. Later it manifested itself in the anatomy of household appliances such as multichannel stereo and surround sound audio set-ups. Since World War I the use of binaural sound localisation and

geometric derivations for pinpointing gunfire positions (e.g., gun 'sound-ranging') have been aimed at counteracting technological developments in supersonic projectiles and air-borne gunships. Subsequently, an emphasis on sound localisation became a catalyst for early sound technologies such as microphone developments (e.g., the Tucker Wire Microphone, ca. 1916) as well as large-scale sound collectors (particularly the experimental mirrors constructed along Britain's Kent coast.
In the 1940s experiments with voice transmission in noisy environments spawned the invention of the environment-less surrounding. The anechoic chamber, a specialised acoustic environment geared towards cancelling sound reflections, becomes the central site where 'transmission' and 'communication' models of sound then propagate.
In such rooms sound is imagined, conceived and developed as a *closed system,* beginning at the *pickup* or microphone and terminating at the *receiver* or loudspeaker. Such ambient-less surrounds also play a role in redefining the soundfield as a series of discrete, isolatable, components that can be reconstructed and analysed. In Jens Blauert's book *Spatial Hearing. The Psychophysics of Human Sound Localization* (Cambridge Mass., MIT Press, 1997), the quantification of perceptual sound localisation assumes the anechoic chamber as the de-facto condition in which to test human capacities to pointillise sounds. More recently gun sound-ranging methods (as well as microscopic versions of the Tucker Microphone) have resurfaced in cutting-edge



sound emanates in the first place [11]. In other words, the whereness of sound is an emergent property of *listening*. Spatial distinctions in sound are testaments of the *transformative* capacities in hearing. Any instance in 'hearing' depends upon radically subjective-*relational* transformations. As environmental eventfulness shakes its way into consciousness, acts of hearing deposit discernible veils over the immensity of vibrational connectivity, creating an increasing sense of *locatedness* in their wake.

Hearing *takes* place. Acts of listening emplace subjectivity and situate eventfulness. To hear a 'place' implies appropriating oscillations and negotiating limits of the self.

SONIC EMPLACEMENT

Hearing sound is about sensing returns [12], while listening *emplaces*. But the spaces within which listeners find themselves are by no means fixed locations. Listening *takes* place, and by doing so transforms hearing into auditory sites. Audible atmospheres are themselves tangible *places*. Hearing sounds means to embody, rather than represent, funda-

surveillance technologies such as pressure array gunshot detectors for public space as well as an ambitious world-wide localisation CTBTO (Comprehensive Nuclear-Test-Ban Treaty Organization) network of sensors monitoring nuclear explosions through infrasound phase mapping.

[10] 'Since Heisenberg and Linus Pauling, the only remaining material bond is resonance. The continuum of visual space of the Euclidean kind is not to be found in the material universe. There are no connections among "particles of being" such as appear in mechanical models. Instead, there is a wide range of resonating intensities that constitute equally wide variety of "auditory" spaces.' (Marshall McLuhan and B. Nevitt, *Take Today, The Executive as Dropout,* New York: Harcourt Brace Jovanovich, 1972, p. 10).

[11] There are no points, lines or planes in sound. In fact, geometry has no sonic equivalence. The thoroughly non-geometric nature of sound is a blind spot in the comparisons between aural space perception and visual space perception. Those comparisons tend to focus instead on clear-cut yet misguided distinctions whereby types of geometry are equated to categories of space (see, for instance, the position between 'linear' and 'circular' space associated with the eye and ear respectively in the chapter 'Visual and Acoustic Space', in Marshall McLuhan and Bruce R. Powers, *The Global Village: Transformations in World Life and Media in the 21st Century,* New York: Oxford University Press, 1989) There are two underlying presumptions, obscured beneath the oppositional polemic where eye is pitted against ear. The first is a notion that spatial paradigms are mono-sensory and somehow hard-wired to sensory organs where each organ provides contrary notions of space. Since the late 1970s the scientific community increasingly explored a uni-sensory model of sensation, where the entire sensorium is seen to be working in tandem to inform spatio-temporal perceptions (Lawrence E. Marks, *The Unity of the Senses: Interrelations Among the Modalities,* Academic Press Series in Cognition and Perception, New York: Academic Press, 1978). The emerging field of 'multi-sensory processes' research conveys systematic efforts to examine interactions among different sensory modalities. But even if we were to accept a proposition that sense organs sustain spatial biases, it still does not account for the fact that there *can* be a liquid sense of vision as much as there *can* be a solidity to sound, if those are aspects the listener is straining to perceive. The second presumption is that ontologies of space are essentially *primary*. If on the other hand we understand sensations themselves to be primary, and spatial perceptions to be *secondary* outcomes of our experiences of being-in-the-world, it opens up the possibility of describing more diverse spatial ontologies as well as relinquishing the necessity to define a foundational spatial ontology in the first place.

Urban surroundings manifest dense, overlapping and often contrasting, sonic spatialities that none the less appear audibly coherent.

mentals of time-space and *self*. Listening is a process of subjective appropriation, where the intimating of the local (conscious and unconscious) also affirms the self. Attention to listening enacts a heightened awareness of one's own self-presence in an embodied auditive field. If hearing can be said to be mimetic of anything, it's not of an environment 'out there' but rather of the *conditions* comprising that specifically situated mind-set, conditions that are at once 'inside' and 'outside'. In other words hearing charts *relations* between subjects and objects that are themselves inescapable polarities of one and the same relational event. Within any atmosphere both observer and the observed are implicit. As such, audible atmospheres are occurrences that manifest halfway between a listener and the vibrations.

SOUND'S SPATIAL MALLEABILITY

Sounds are spatial ambassadors. They

[12] Delayed and altered repetitions situate audible impressions. Returning sound coupled with returns of perceptual memory forms the expansiveness experienced in hearing. Every instant of perceived hearing is already a thickening of recursive operations piling into the present tense. Delayed recurrence sharpens the sense of location, the expanse of which ties into a reciprocal breath of memory. In more general terms, delays produce states of relative permanence, by altering their rate in relation to the rate of becoming. In order for vibrations to escape their evanescence, vibrations must leave aspects of themselves behind by somehow overtaking their own rate of becoming. It would seem that delaying also involves a form of acceleration. And it is through setting portions of environmental becoming into delays that surroundings can become conscious of themselves.

[13] Sounds always arrive from *elsewhere*. To hear a sound means to register frictions in that journeying. In *Fray,* microphones located in the upper vault of the Dürnstein tunnel pick up the specific echo reflections and resonances of the tunnel, filtered through the material properties of the ceiling vault and multiplied again by the resonances of the technical access tunnel in which the microphones are located. For the live amplification in the installation upwardly oriented and remotely placed loudspeakers are used to render diffuse sound. All sounds coming from loudspeakers rebound at least once off the interior of the tunnel chambers before arriving at the listeners to enforce a non-localised, yet distinct sense of spaciousness.

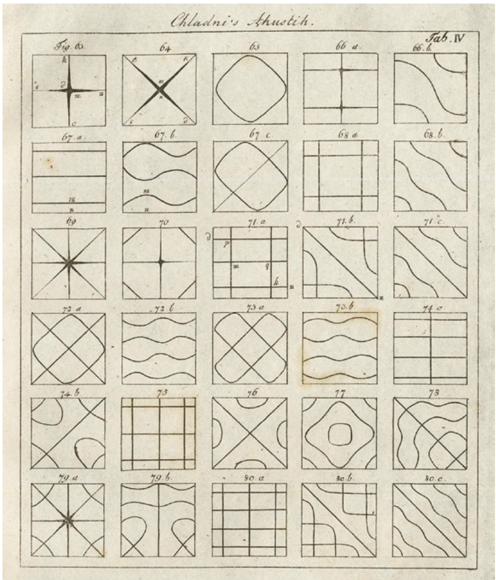
[14] Recording and amplification technologies are spatial multipliers. They act to transport and preserve sounds into unforeseen contexts and meanings. Live amplification methods balance vibrations that travel every-which-way at the intersection where the microphone is placed. The microphone pulls vibrations away from their immediate material agency and re-routes them instead down conduits with displacing or retentive properties. Whether piped through wires or radiating out of antennas, electromagnetic transduction only serves to magnify processes already inherent to the journeying of sound.

[15] The inherent plasticity of sound is readily apparent through recording technologies – early gramophones and tin foil players were purely hand-cranked mechanical devices. Consequently small changes in playback speed altered the pitch and aural perception of the recordings. 'If the cylinder be rotated at a given speed while registering certain tones, it is necessary that it should be turned at precisely the same speed while reproducing them, else the tones will be expressed in entirely different notes of the scale, higher or lower that the normal note as the cylinder is turned faster or slower (...) Differences in the velocity of rotation (...) would have the

curious effect of possibly converting the high voice of a child into the deep bass of a man, or *vice versa*.' ('The Talking Phonograph', in *Scientific American,* 22 December 1877, p. 385).

[16] The everyday auditory surroundings include many overlapping categories of vibration which are latent within diverse spatialities: Vibrations in the air make room volumes palpable; material vibrations transmit sounds from beyond those spatial confines and convey the interiority of materials atmospheric variations themselves become audible in wind and precipitation; loudspeakers in public announcement systems, intercoms, and telephones superimpose dislocated spaces. Although the soundings are continuous, the continuity is stratified by multiple intermingled spatialities through which the listener effortlessly wanders. Pick-up points for *Fray* intentionally side-stepped over-determined sound sources and instead materialise unstable ambiguous presences in the surroundings. By oscillating foreground/background distinctions in hearing, bodies and spaces began to propagate one another.

[17] *Fray* begins with the question of auditory coherence, seeking ways to listen towards comprehension without reaching distinctive meaning. The research phase of *Fray* tested spatial and temporal displacements as well as sound cancellations and timbral-dynamic alterations of live sounds in the outdoor environment. When working on-site in the Wachau with live amplification, the resilience of the auditory field quickly became apparent.



mediate physical locations by exceeding the confines from which they come forth, but at the same time they carry imprints from their particular contextual origin [13]. Vibrations cut across discontinuities in networks of connectivity [14]. At times they seem to construct spaces all of their own. The plasticity in sound creates an infinite variety of formations melting into one another [15]. In territories where human habitation bears strong imprints such as cities and other engineered landscapes, audible surroundings manifest multiple interlocking spatialities [16]. The magmatic character of our experience of sonic spaces also renders them resilient to deformations. In fact, the more one tugs at the threads of auditory realism, the more tightly those threads coil around our own stubborn sense of reality [17]. Nonetheless in places where fraying occurs, the result is not so much a distortion of the 'real' as much as it is a momentary awakening from the slumber of everyday experience. Familiarity is a perceptual wake propagating at the same rate as

Aural perceptions seize vibrational affordances and by doing so stratify sound. Predominant social practices circulate such strata, enforcing certain auditory models over others.

Subtle transformation in the soundfield tended to fuse into the rest of the auditory scene.
It was surprising to hear just how plausible much of the live amplification strategies became in such outdoor situations. This implies not so much a failure of the initial intuition as a displacement of the underlying hunch: While intensifying ambient atmospheres the auditory scene is emptied of its object-laden content only to reveal an even tougher lining of temporal relations. At this level of the auditory weave, or texture, the very knotting of time appears meaningful. In other words undermining distinctions of near/far, inside/outside only gives rise to another attention, and instead of dissolving into eventfulness, it produces an alternate focus on the heterogeneous currents of temporal strata.

our becoming. Delaying perceptual familiarity opens up a myriad of affordances into that becoming. By denaturalising the 'real' our sense of reality starts working against itself [18].

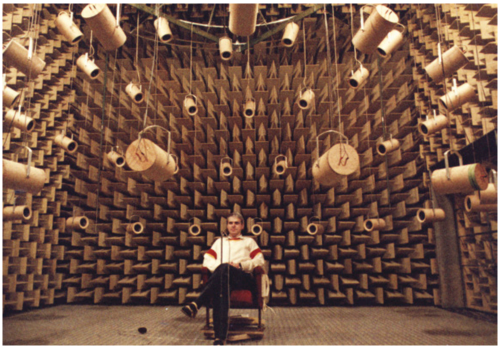
AMBIENCE
AMPLIFIED

Recordings have the uncanny ability to contain environments. Recording a conversation outdoors inevitably means registering the 'outdoors' in the signal. The surroundings intrude upon conversations in a manner that ensures signals will *always* deliver more than the messages of the sender. The more one attempts to 'isolate' signal sounds in a recording the more the ambient pushes to the fore. From the perspective of the signal, there are no clear-cut distinctions between spatial, chromatic or linguistic aspects of vibrations in the first place [19]. The stratification reflex that tends to break continuities into distinctive layers and categories seems to be a fundamental part of our consciousness of sound. However mistaking these strata to be actual existing borders within vibrations themselves leads to misconceptions in the nature of sonic eventfulness [20]. Viewed in a different light, one could say that a central *operative* mode in sound, in general, rests in the tension between fluid continuity and discrete individuation.

[18] Revealing the nature of a site paradoxically involves modifications to that site. The realisation of *Fray* involved identifying, intensifying and reworking the latent atmospheres of the Dürnstein tunnel to get closer to the inner oscillatory workings of that site.

[19] Categories such as voice communication, sound reinforcement, commercial recording, and sound reproduction demand an extensive implementation of technical know-how implemented in detailed models of sound. Sound modelling includes the selection, parameterisation and optimisation of perceptual, acoustic and computational categories of sound. Common to all these categories of audio production are highly efficient, yet reductive, models of sound and hearing. Arguably, the prevalence and exposure to such audio techniques conditions modes of perception that then are projected back onto the environment in a way that confuses models of reality with vibrational reality itself.

[20] Multi-track sound editing and synthetic sound field simulation technologies can give the impression that ambient sounds are composed of discrete parameters that can be added or subtracted from foreground sounds at will. On the other hand trying to reverse-engineer a single channel ambient recording into multiple tracks is an impossible task. Likewise an ambient effect such as reverb can be *added* to a signal but it is virtually impossible to create an inverse filter, or deconvolution algorithm, that retrieves the original non-reverberant signal.



Raviv Ganchrow, *Fray*, site-specific sound installation, 2012, commissioned for Kontraste Festival, *Electric Shadows*, Krems, 2012.

SPECTRAL ANALYSIS

Interview with Justin Bennett

Arie Altena

'In 1635 a plague-house was built on what is now the WG Terrain in Amsterdam. There was a hospital on this site until 1983. Dr. Ernst Hartmann (1915–92) observed that some areas in a hospital were more conducive to healing than others. He determined that a grid of radiation covers the Earth's surface. At some points, these lines form a "Hartmann Knot" of negative energy. Hartmann's work has been related to the study of ley lines and *feng shui,* as well as to Wilhelm Reich's orgone energy'. This is the text for Justin Bennett's soundwalk *Spectral Analysis WG* (2013) a fiction in which he attempts to reveal energy phenomena in and around the WG Terrain while investigating properties of sound and electricity. This interview is an edited transcript of a public interview about *Spectral Analysis WG* that took place on 6 February 2013.

Arie Altena For Sonic Acts you made a new soundwalk, *Spectral Analysis WG*, which takes the same theme as *Spectral Analysis*, the soundwalk you made for the Kontraste Festival in the small Austrian city of Krems. How did you develop the idea for these soundwalks, which are concerned with electromagnetic phenomena and the science, the myths, and the crackpot theories around them?

Justin Bennett The history of electromagnetic experiments is something I have always been quite interested in. There is a weird connection between avant-garde arts that use new media and the occult, which sometimes comes out and is sometimes suppressed. There is for instance the influence of theosophy – which is based around the idea of seeing auras – on abstract painting. It's related to the way that artists look for what is beyond our visible reality. The history of early experiments with electricity and electromagnetism seems very much connected to esoteric theories. If you go back to the eighteenth century you find Franz Anton Mesmer, who was a key figure in my soundwalks for Krems and the WG Terrain in Amsterdam. In my narrative he visits the hospital at the WG site. There are so many crazy stories about Mesmer that it doesn't really matter if you invent a new one or not. The reality is even crazier than the fiction. Mesmer was convinced that there was a magnetic fluid, which somehow connected every living thing, even inanimate objects. He thought that if you drank a glass of water that had been magnetised, it would affect you by working on the flows of magnetic fluid inside you. He was convinced that it worked because he really was able to cure people of all sorts of things, even blindness. The current view is that he didn't realise what he was doing. What he did was something between hypnotism, suggestion, and manipulating the unconscious – in itself an idea that did not exist in the eighteenth century. The theme of 'spectral analysis', which now comprises two soundwalks, and is developing further into other things, is about this other, spectral world. That other world could be the dark universe, invisible phenomena, ghosts. The idea is that you can use technology to tap into it and listen to it. That is exactly what early experiments with electricity were trying to do.

AA Your soundwalk focuses the attention of the audience very much on certain types of sound, for instance environmental sounds, through the fictional story that you tell. This happens because you lead the listener to certain spaces with specific acoustic qualities and you overlay it with recordings you made on exactly the same spot. Sometimes that leads to an almost spooky layering of sounds – especially when you're wearing headphones that don't shut you off entirely from the environment so you still hear the sounds of the street as well. And then there's the fictional story that focuses your mind in a certain direction… This is not really a question. I could ask, is this intentional...

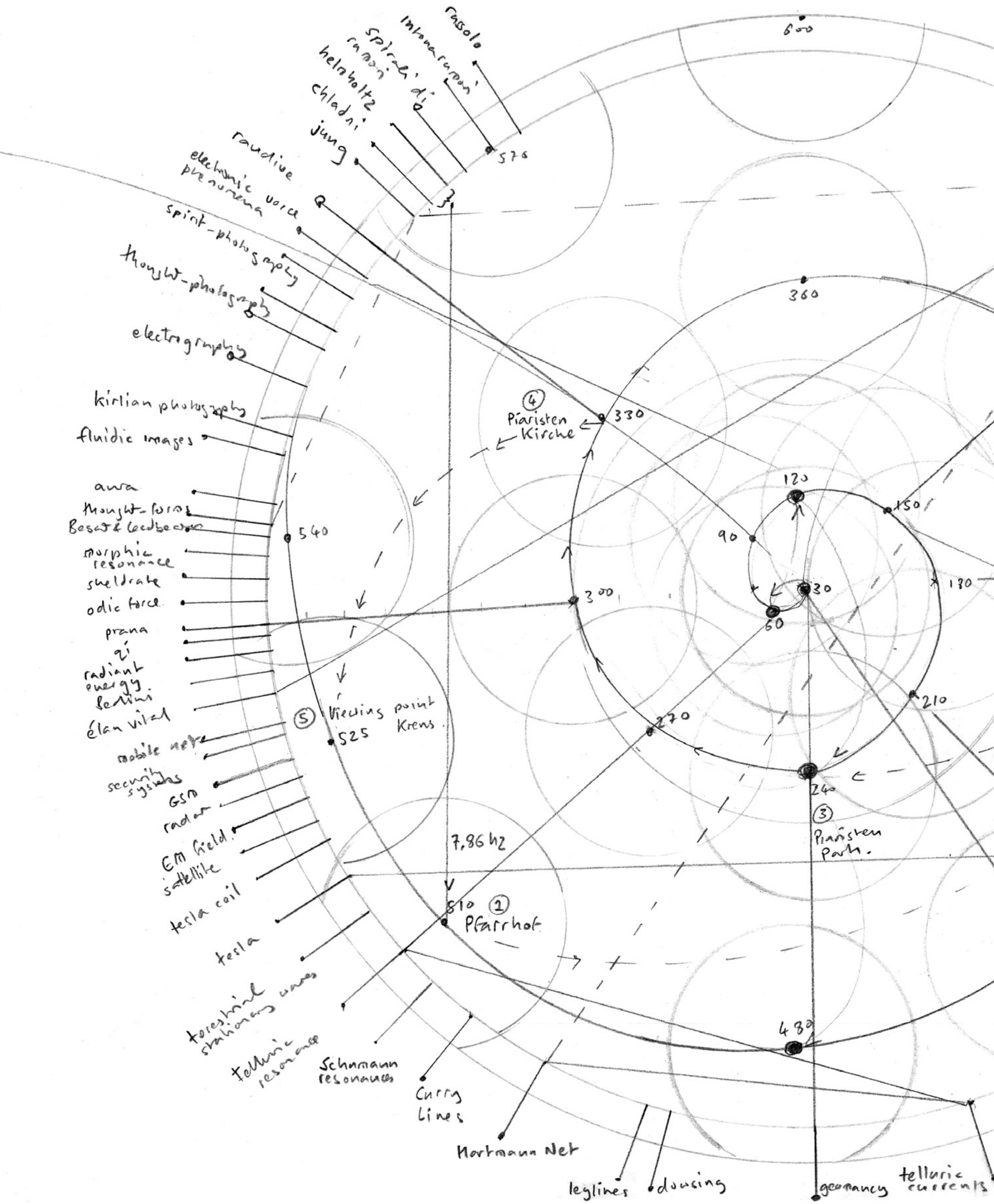
JB And I will say: 'Yes'.

AA Do get the idea for the story first, or do you begin with recordings?

JB It's a bit of both. If it's possible, like it was in Krems and Amsterdam, it involves a lot of hanging around in the space. The space itself is crucial, the feeling it gives you. I take something of the atmosphere, or of the ambiance of the place, maybe tweak it a little bit, to direct your attention to something, to make you feel it in a slightly different way. Generally the most important part of a soundwalk like this one is to define the route. The route determines the timing, it determines the structure, and to a certain extent it determines the story – certainly for *Spectral Analysis WG*. It also determines the whole visual aspect, because what you see during the walk is part of the experience. What you see is what you see there normally, but you see it in a particular order. Making a soundwalk is almost like making a film. You can direct people's attention; you can say, look at this, or look back to where you came from. You can actually suggest how they should view the environment. A soundwalk definitely focuses on hearing, certainly if you aren't used to listening intently to environmental sound, it can be an ear-opening experience – but it is also about looking. It makes you see the world in a different way.

AA One of the effects of a soundwalk is that it can make you aware of the fact that there are many forms of listening, that listening is multidimensional. It enriches the awareness of listening...

JB Listening is an issue that occupies many people who work with field recordings. What is sonic reality, how do you listen to it? What is your relation to the acoustic environment? This is a layer in my work as well, even in a piece as fictive and electronic as *Spectral Analysis*. When I'm walking around, I find myself switching between different ways of listening. There's a kind of navigational way of listening (you hear something, and follow that sound, for instance), there is listening for meaning (for instance, when you listen to language), there is listening to music. You normally listen to environmental sounds in a different way from how you listen to music. But



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2 Pfarrhof
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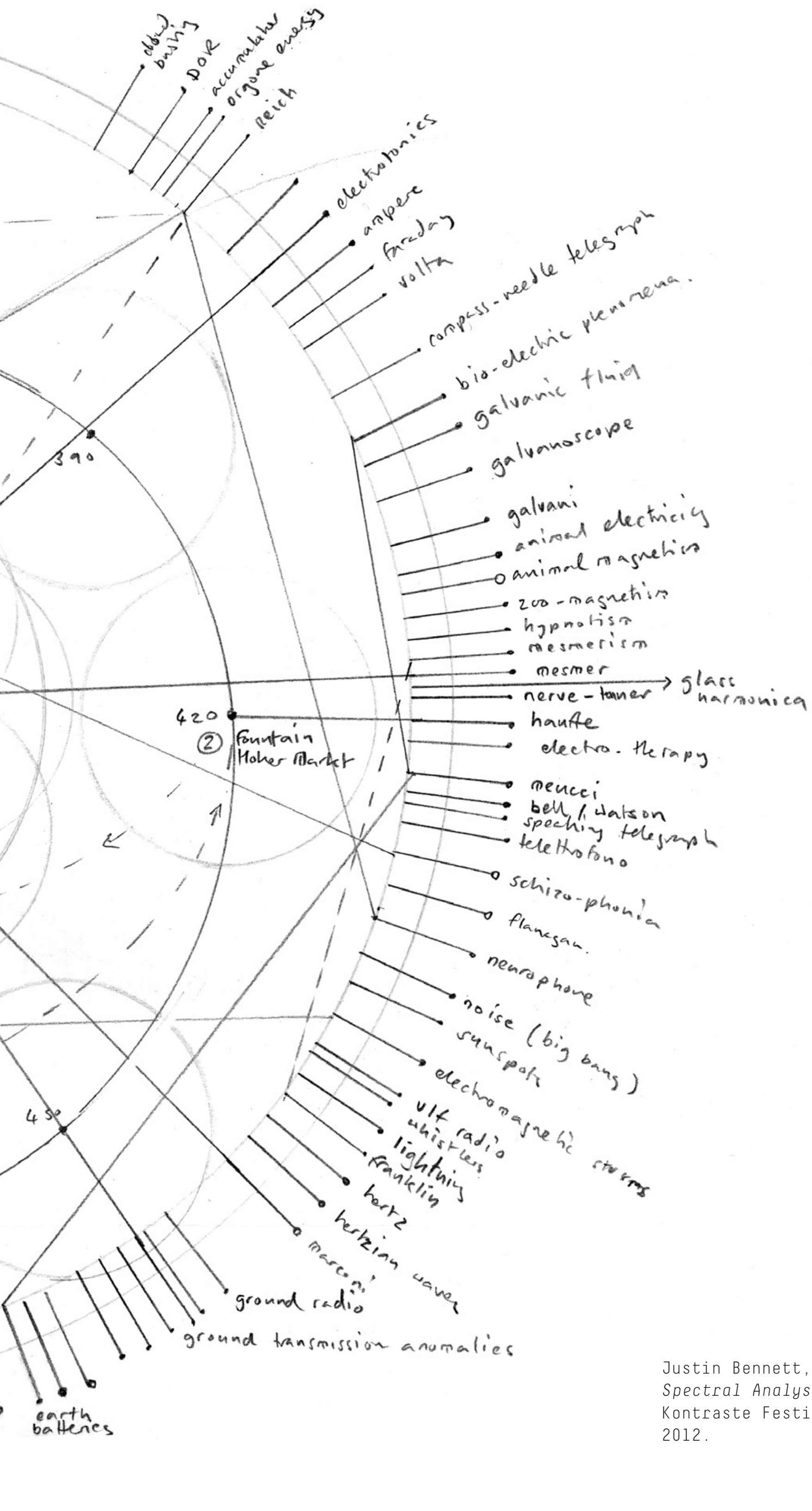


Justin Bennett, sketch for the soundwalk *Spectral Analysis*, 2012, commissioned for Kontraste Festival, *Electric Shadows*, Krems, 2012.

by changing the sounds, or putting them in another context, you can switch the mode of listening, and you start hearing environmental sounds as music. Many people have the experience after doing soundwalks – not just mine – that when they take the headphones off they start listening in such a sharp way, that they hear everything as music. I like playing around with the boundaries: when does a sound become musical, when does it become part of the story, or when does the story become an instruction, telling you where to go?

AA There is a marked narrative and fictional aspect to your recent soundwalks, whereas your earlier soundworks were closer to field recordings...

JB I do not really know why that is. It has partly to do with working with the form of the soundwalk, which gives you the opportunity to tell a story. I think of moving through the city as a form of drawing. It is like making traces, and recording is also like making traces. If you listen to a recording of somebody moving through a city, it's as if you are taking part in a journey. You are listening through their ears, you are following them. So also in my earlier sound work there was already a movement towards narrative. Now I indeed use the soundwalk as a way to tell stories. Soundwalks are a great form because you can do all sorts of things in them. You don't have to create narratives, there are soundwalks that work very powerfully just with sound, presented without any text at all. You get an instruction to walk in a direction, or be in a certain place and listen. This coupling of a spatial and visual environment to a presentation of sound has a very strong effect.

AA In *Spectral Analysis* for Krems the person participating in the soundwalk is also the actor. The story is in the second person. The listener is put in a position, instructed, for example, to go stand near that fountain, put your hands on the iron bars. You are enacting the story by doing the soundwalk. In *Spectral Analysis WG* you listen to a third person story. It's about another person and there is more distance. Why did you decide to do that?

JB In Krems I was really interested in creating a narrative structure, but I also found it interesting to include the sound experiments that I recorded there in the soundwalk. You are listening to the sound experiments as if you are doing them yourselves. In the Krems version there was no spoken voice. The story was printed on a sheet of paper that you received at the start of the walk. In Amsterdam I first tried to do a similar thing. I wrote a story, telling you what to do. But I found it very difficult to find the right tone. The WG buildings were once a hospital and therefore I decided to use the perspective of a patient who is conducting his own electromagnetic experiments. You are listening to a recording of the doctor telling you what this patient did. It obviously happened in the past, but you are still listening to it as if it happens in real time – you are hearing the experiments they apparently did together. Reading a story for yourself and listening to a voice telling a story are very different situations. If you read it, it is almost as if you are reading it in your own voice. You are the person who is telling yourself these things. If you have a voice coming through the headphones, there really is somebody else present telling you the story. I was curious if it was possible to become immersed in a story despite this distance of a third-person perspective. How far can you push that, and still make it an immersive experience?

AA You just said that this material is leading you in new directions. I was wondering, have you ever made a radio play, as that's a form that is quite close to what you are doing now?

JB I have done some radio projects that were more conceptual. They were about space, or the city, where I was taking sounds from one place and broadcasting them somewhere else. At the moment I'm working on a radio version of the soundwalk *Telettrofono*, by Matthea Harvey and myself, which is about Antonio Meucci, the Italian inventor of the telephone. He invented instruments for the theatre and was also interested in electricity and specifically in electrotherapy. He inadvertently invented the telephone when he was trying to cure somebody through electrotherapy. He gave his patient, who was sitting in another room, an electric shock and that person cried out. Meucci heard that cry through the device he was using to give the person the electrical shock and realised that the voice was somehow transmitting through the wires. That led to the telephone. Just as with *Telettrofono*, some of the material of *Spectral Analysis* could work well as a radio play, but I would have to structure it differently, and you probably need more explanation, as you miss the visual and spatial experience. Actually when I started to work with sound, music and text, I did not really have a context for that form of composition. I began to think of it as a radio play, as *Hörspiel*. You could just think of a time slot, say twenty minutes, and imagine a piece for people listening through a loudspeaker. It was a way of thinking about working with sound. Like a soundwalk it's a form. It's a form I like.

GEOGRAPHIES OF FLICKER

Interview with Matthijs Munnik
Arie Altena

In Matthijs Munnik's *Citadels: Lightscape* flickering lights combine with sound to produce a stunning colour experience. The flickering lights trigger in the viewer the sense of 'seeing' colours and colour combinations that are not actually there. This interview took place in Amsterdam, in October 2012, two weeks after Matthijs Munnik's performance of *Citadels: Lightscape* at Kontraste in Krems, Austria.

Arie Altena Could you explain how *Citadels: Lightscape* works?

Matthijs Munnik The version of *Citadels: Lightscape* I showed at the Kontraste Festival is a light wall incorporating a large number of LEDs. The wall is illuminated with very diffuse light. The frequency range of the LEDs is between 0 and 80 Hz and I use them to create intense stroboscopic patterns. The light wall changes colour very rapidly, using various combinations and patterns I program into it. One kind of pattern is when you see green being alternated with its complementary colour magenta, and with black. The colours, patterns and frequencies interfere with the signal the retina sends to the visual cortex of the brain. The effect is that you see different patterns, colours and shapes. It's like a hallucination. I can adjust the colours, patterns and frequencies live, and by selecting a certain sequence I can increase the effect. My hope is that the audience goes into a kind of meditative state. I also play around with the intensity of the light. I can gradually dim the lights so that your eyes perceive the dimmed lights as bright. If I then bring up the intensity really quickly it fills your entire field of vision with colour and the whole light field seems to come free of the wall.

AA While explaining, you were making movements as if you were opening and closing faders. Do you control the patterns and colours using channels on a mixing desk?

MM I select an RGB colour – green for example – for the first channel, and I'll link it to a pattern. I've got six patterns and I know what effect each of them has on the eye. The pattern is created through the alternation of colours. There are four 'stages' to it. I set the frequency, and I might know, for example, that if its complementary colour magenta is on the third channel, it'll have a specific effect on the pattern. So I can fade out that colour on another fader, and then you'll only see green flickering, and if I then fade in the third channel, you might see strange discs or some other sort of pattern.

AA Did you invest a lot of time studying the effects of different combinations?

MM That's what took up the most research time: I experimented with it for at least two years, on and off. After a while you begin to understand which combinations of colours and patterns work. You know it's working when it produces interesting patterns. There are a few specific frequencies that generate a strong visual effect when combined with colour patterns such as stripes or discs. And there are lots of combinations that don't work. The first step in the research was to find out what did work and the second was to explore their different potentials and then do more experiments with them.

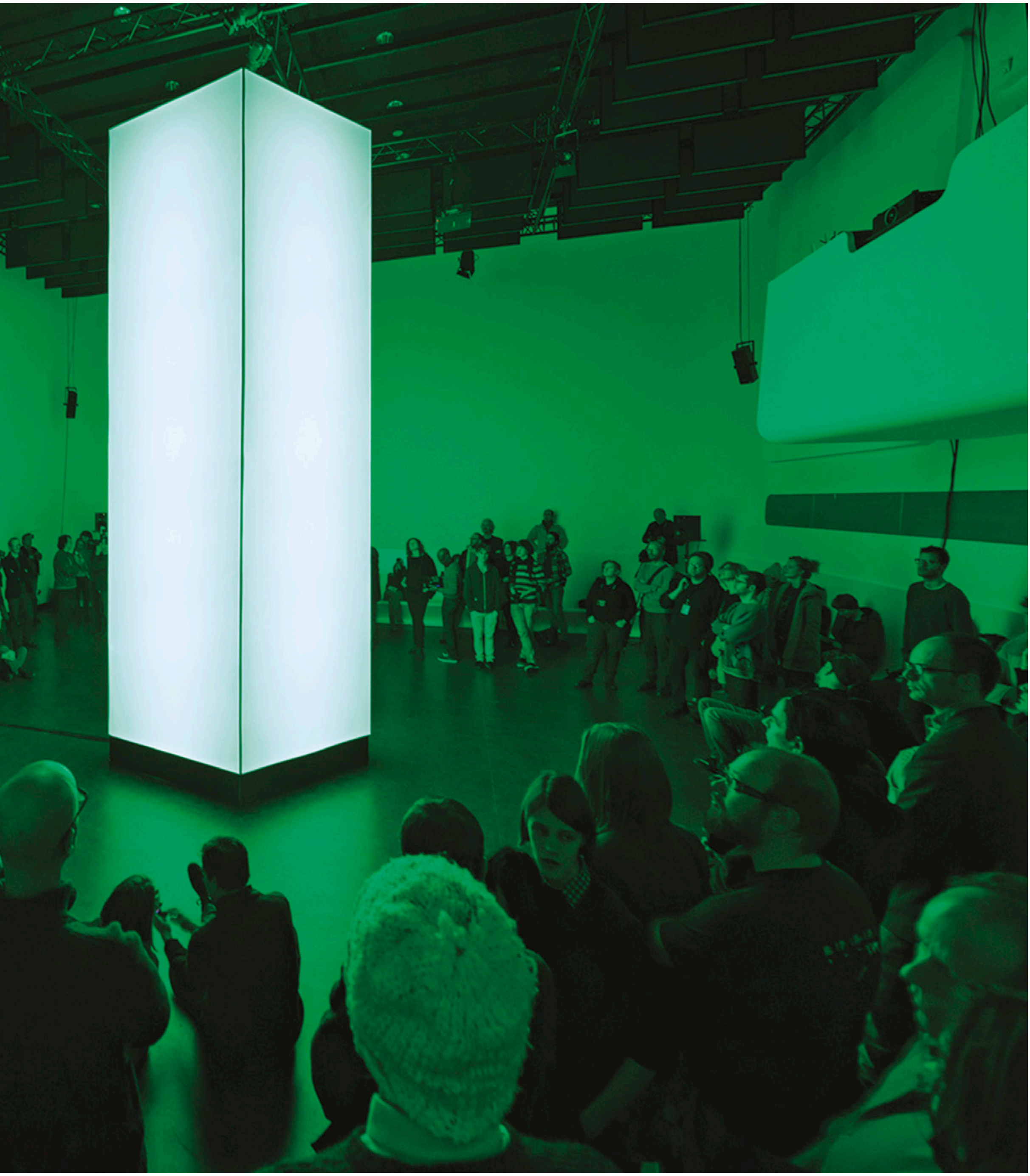
AA You're also playing with perception. The viewer 'sees' patterns that aren't there...

MM What I'm most fascinated by is that 'flicker' is raw and direct. You can set it in motion, but exactly what happens is beyond your control. Seeing things they don't normally see frightens some people. They might wonder if it's safe – if it could damage their eyes. But you keep on looking. It's an experience that verges on the sublime. I recently read an interesting article that gives a mathematical explanation for why we see particular patterns when watching films and installations that use flicker. The conclusion was that flickering can generate certain interference patterns due to the architecture of the retina – the way the cells are connected within the eye, and how they link to the visual cortex. Once they get to the visual cortex, these patterns go through the same transformations as our normal visual input. The patterns are transformed into the spherical shape of the eye, and this results in characteristic tunnel shapes. So by examining these flicker patterns you're actually studying the architecture of your own eye. I find it intriguing that many of our religious symbols correspond to patterns generated by flicker or other hallucinogens. I'm attracted to the idea that these symbols don't just have symbolic religious significance, but that they have physical origins in the architecture of our eye.

AA What is the relationship between your work and the history of the sublime and of colour experimentation in painting and film?

MM There's a long history of art that concerns colour or the relationship between colour and sound. Opportunities for combining colour and sound go hand-in-hand with technological innovation. People experimented with colour organs from the mid-nineteenth century to the beginning of the twentieth century, and colour experimentation in film started around 1920. Colourfield painters try to capture the sublimity of colour in paint. Marc Rothko was a master at bringing colour to life on the canvas. Then in 1961 there was the *Dreamachine* by Brion Gysin and Ian Sommerville, which was the first use of stroboscopy in an artwork. That was followed by Tony Conrad's film *The Flicker* [1966]. The arrival of computers brought new ways of experiencing the sublime through technology. It goes a step further each time.

Matthijs Munnik, *Citadels: Common Structures*, installation commissioned for Sonic Acts, 2013, Stedelijk Museum Amsterdam, Sonic Acts *The Dark Universe* festival opening, 2013.



Matthijs Munnik, *Citadels: Lightscape V*, installation, 2012, *The Dark Universe* exhibition, NASA - New Art Space Amsterdam, Sonic Acts, 2013.

AA: You use very powerful LEDs in your work, and that allows you to play in a very controlled and subtle way with nuances of colour, frequency and light patterns. You have tools at your disposal that the makers of colour organs or the flicker films of the 1970s could only have dreamt of. Is that difference in technology important? You can do something that would have been impossible for Paul Sharits using film, or Marc Rothko using pigment.

MM I can't work with that same intensity and precision without the LEDs. And I can't generate such a rapid flicker without the technology. So *Citadels: Lightscape* couldn't exist without LEDs. But Sharits and Rothko perhaps created much subtler work with the technology available to them, than I am now. They had their own solutions to achieve the desired effect. Sharits layered projections on top of one another, which caused interference. I want to get to the point where my work is subtle and overwhelming. I'm not *making* the flicker world, I'm opening up a window onto it. In his lecture at last year's Sonic Acts [2012], the author John Geiger talked about 'geographies of flicker' that still need to be explored, and I find that an interesting thought.

AA What do you mean by that?

MM I see the flicker world as a sort of virtual layer in our reality that is outside the bandwidth of normal perception. It's concealed in the visual world of the eye itself. We've been aware of its existence since the nineteenth century. The Czech scientist Jan E. Purkyně was one of the first people to write about. He discovered it by moving a hand in front of his eyes while looking at the sun. The flicker world is normally invisible, but some art – including my own – gives access to it. I don't create the flicker world; I try to compose an entrance to it.

AA In your work *Microscopic Opera* we see a projection of the world of the tiny worm *Caenorhabditis elegans*. This seems to be an entirely different kind of work.

MM It is an entirely different work, but there is a single overarching theme. Like *Lightscape*, it reveals a hidden world. It opens a window onto a world that normally eludes our perception – the microscopic world of micro-organisms. *Microscopic Opera* is a way of shifting the sensory focus to a hidden domain. We live in the same world as micro-organisms, but to the eye they are almost separate dimensions. The difference in scale is so huge that we're almost entirely unaware of the microscopic world.

AA In a more recent work, *Truest Green*, you attempt to do the impossible and show us pure green light.

MM We never see pure green. Most people have three types of cones in their retinas, for red, green and blue, each for a series of wavelengths that determine whether something is red, green or blue. But if you're looking at something green you'll also see a bit of blue, and the red cone cells are also always firing. The same is true if you're looking at something blue, but less so. What I do in *Truest Green* is first show a composition consisting only of red light until your eyes have totally adapted to the red. At this point the red cone activity subsides, the white balance in your eyes automatically adjusts itself if just one colour keeps firing. If activity in your red cones has been completely subdued and then you look at something green, then you're looking almost exclusively with the green cones. That's something that never happens normally. So when I show green at the end of *Truest Green* you see a really strange kind of green, something you've never seen before.

AA How do you combine sound with your visual work?

MM The first half of *Citadels: Lightscape* is a sort of soundscape prelude, with the harmonics coupled to colour. The modulation of the sound then parallels the frequencies of the flickering of the light. Sound plays a supporting role. It brings focus and contributes to a meditative atmosphere. For the audience, it heightens the sense of being immersed in the work.

AA Could you also work without sound?

MM You'd think so, but strange things happen because of the sound. Listening to white noise at the same time increases the intensity of contrasts and complementary colours. There's a link between sonic and visual experience. Certain sounds intensify certain kinds of images or the effects of specific colours. And the effect is intensified if you hear the same modulation in the sound as you see in the light.

AA Why do you sometimes present *Citadels: Lightscape* as an installation and sometimes as a performance?

MM The two versions lend themselves to different experiences of the work. An installation is calmer and you can take your time exploring the space. When I perform I'm taking the spectator into another world and there's a direct link between the patterns I see and create and what the spectator sees. There's always something magical about doing it live. I'm at the controls and I see the same patterns as the audience – it's going directly into the brains of the people watching. If I move a single button it changes what they get to see. There's a set composition, but there's space for improvisation.

AA How did your interest in flicker come about?

MM Well it was actually through William S. Burroughs. There's a nice Burroughs quote that goes, 'Anything that can be done chemically can be done by other means'. He saw the *Dreamachine* as a revolutionary object: bringing enlightenment to humanity through machines. It's an interesting utopian idea, I think. It would be great if we could get the right technology and use it – or abuse it – to conjure up new sensorial worlds, instead of enveloping ourselves in a digital bubble that closes us off from the world. I think that the simplistic app culture is holding back the potential for intense technological experiences. Perhaps there's a role here for media art.

AA And in your live performance you do create a personal presence – and you throw the audience back on their own resources.

MM That's what I like about Bruce McClure's performances. They completely throw you back on your own resources. There's nothing you can do but submit to it. You go in and there's no way out. One doesn't usually do that sort of thing.

AA After seeing McClure's performance at Kontraste the Australian musician Robin Fox enthused that, 'At one point it violently put me asleep!'

MM Yes, that's beautiful. It's a really strange reaction, but that's exactly what happens. It's really overwhelming. It's loud and it flickers and you sink into a kind of dream state. That's the way I want to go with my performance too: it has to have an even greater physical impact. It needs to become dangerous, as it were, because then the sublime can manifest itself – something you can't control... something bigger than yourself.

TO SWAY IN SOUND

Interview with Yolanda Uriz Elizalde

Arie Altena

The work of Yolanda Uriz Elizalde, who studied music and ArtScience in The Hague, ranges from experimental music to installations. Her immersive installation *~~Kulunka~~* (2012) evokes visual, auditive and tactile ways of perceiving vibrations. This interview took place in November 2012 after the Kontraste Festival, and was edited after the Sonic Acts festival.

Arie Altena *~~Kulunka~~* was shown at both the Sonic Acts exhibition and at the Kontraste Festival. What are you aiming at with this work? What do you hope people will experience?

Yolanda Uriz The fundamental idea of the installation comes from perceiving sound through other senses. The title *~~Kulunka~~* literally means 'to sway' in Basque. The initial idea was to create an immersive experience based on my explorations of sound as a phenomenon. I was researching how sound behaves in liquids, how it behaves in solids, and how it behaves in the air. How can we perceive sound differently, or perceive it in various ways? The underlying question is, how can you perceive reality from other angles? The installation is a darkened room with platforms on which the audience lies down. Infrasonic frequencies are played through speaker membranes that are placed in a container with water, making it vibrate. This creates ripples in the fluid, which are projected on an undulated screen hanging from the ceiling. The platforms also vibrate sonically. I use pure sine waves, without any harmonics, for the speakers in the water and as the sound that is fed into the solid materials. The frequencies that are played through the speakers in the water are also the building blocks of the audible composition that is spatialised by using four speakers in the room. The composition uses the harmonic series of the infrasonic frequencies, so that the relation between what you see (the ripple patterns created by the infrasonic frequencies in the water) and what you hear (the audible composition) is one-on-one. It's analogous, both compositions develop in parallel.

AA And how do you make the platforms vibrate?

YU There are two transducers in the platforms. Sound behaves very differently in solids than it does in the air or in a liquid. All the paths of the soundwaves are felt by the body, which is in contact with the solid material through which the soundwaves travel. The transducers also interact with each other, and that creates patterns. I didn't need four transducers per platform (comparable to the four speakers in the water and four in the room). The reason is that two sine waves already interact in the material. You feel the nodes from the intersecting waves in a different way. What you feel in your ankle has another rhythm than what you feel in your shoulder. If a platform has more than two transducers the interplay is too complex, and the relation with the other elements in the installation is lost. Two sound sources in the solids were more than enough.

AA What frequencies do you use for the speakers in the water?

YU Those frequencies go from 4 to 18 Hz, though there is one point when the pitch rises to 50 Hz, which is already in the human audible range. But that's only for a very short moment. I started including it since the Kontraste Festival; before that all I used was infrasound.

AA Do you try to find a fusion between the ears, eyes and the tactile senses, or do you primarily want to make listeners more conscious of how we 'hear' with different senses?

YU The fusion of the senses happens within the person experiencing the installation. The senses are already put together in our bodies. I studied classical flute at the conservatory, and sonology in The Hague. I have always been more of a performer than a composer. I came to experimental music as a performer, through playing improvised music. When I'm performing I am always completely immersed in the sound. This experience of playing music is something I wanted people to feel in *~~Kulunka~~*. I wanted to transfer the experience of playing music, creating sounds, and being completely into it, to an audience. As a performer I was never sure if the audience was feeling all the things I did. The experience of hearing music is different for the performer and the audience. I always hoped to put the audience in the position of the performer. When you play music – certainly when you play the flute – the whole body vibrates with the sound.

AA What music did you play?

YU I used to play acoustic improvised music. For a while I also had an electronic 'instrument', which I used to process the sound of the flute. I really needed a break from my purely classical music education. A lot of work went into the improvising, lots of rehearsals. But the music was always improvised, because I wanted to have the experience of really being in the moment, of being complete aware of where I am when I play. When you are really in the moment, and are completely aware of that moment, that's immersion. I think it is something that society looks for and longs for; its something that people need. That's why we have meditation practices – to help us to silence our inner voice. We still aren't fully aware of this in our society. We also miss out on the tactile sense, with all our digital information. In *~~Kulunka~~* I try to give people an experience of being immersed and totally aware of the moment.

AA How did you get from studying flute to experimental music?

YU I was always more interested in contemporary music. As a flute player I liked to work directly with composers. I enjoyed the sonic realms of the people who studied at sonology much more than the world of classical music. I learned about the endless possibilities of processing sound. It brought me closer to my own time.

AA You are exploring the physical and tactile aspects of sound, and you were a flute player. The flute does not strike me as a very physical instrument...

YU On the one hand you're right, but you're also wrong. If you take a double bass, the instrument will vibrate, and when you hold it that is what you feel. The flute is the only wind instrument without a horn. That means it has to resonate in your body. The sound comes from the player. For me learning flute technique was a bit like yoga. It's about finding the resonance of the instrument in your body. Playing the flute is really physical. That experience spurred my interest in the tactile aspects of sound.

AA How is the audible composition of *~~Kulunka~~* structured?

YU It's a fixed linear composition. It develops in parallel with the infrasonics that are used for the speakers in the water. Whenever I use 4 Hertz in the water for instance, it comes out multiplied in the audible frequency range – so 4 Hertz become 8, then 16, 32, 64 and so forth. What you hear is a synthesis of several harmonics. The pitch slowly rises through the infrasonic range, reaches a climax and then descends. You also hear that through the synthesis in the audible range. For me the most important aspect of the installation is the experience of the visitors. They have to immediately 'grasp' what is going on. For *~~Kulunka~~* to be clear and effective, the composition had to be fairly simple. The audible composition starts with low beats, but not the lowest, and slowly introduces more elements. It builds up in a more or less random way – in any case not in a totally linear way – and then it descends in a linear way, synchronous with the infrasonics. Of course it's a very conventional way of structuring. It slowly ascends, reaches a climax and then descends. But it works. The first version of *~~Kulunka~~* was built for one person only and it had a clear beginning and end. Now the installation is for multiple people and sometimes people enter halfway through the piece. Some people come in at the climatic moment. They also stay in for longer than one cycle. I like that random aspect. The first version of *~~Kulunka~~* was only seven minutes long and then people were supposed to leave. The composition is now twelve minutes long.

AA My experience is that when you stay for a longer time in the installation, you begin to hear 'more'. Like a drone that initially sounds quite boring, but which reveals its richness over time...

YU You need a little bit of time to get used to what is happening in *~~Kulunka~~*. The physical experience is important. It takes time for your muscles to relax. Once your body and mind have relaxed enough, you begin to hear more richness in the sound. There is also the stroboscopic light in the installation, which affects your alpha waves. It doesn't induce you to see patterns – as is the case in works by Matthijs Munnik or Tina Franke – but it certainly affects your way of seeing things and that in turn influences your hearing. I guess the longer you are in the installation the closer you get to a certain state.

AA Could you elaborate on the research you did into how sound behaves in different media? What did you find out?

Yolanda Uriz Elizalde, *~~Kulunka~~*, immersive installation, 2012. *The Dark Universe* exhibition, NASA - New Art Space Amsterdam, Sonic Acts, 2013.

YU: One thing I always assumed is that men are able to handle the tactile aspect of sound better than women, because they are generally built stronger. It turns out to be exactly the other way around. The physical experience of sound is something that women would like to be stronger, but men wouldn't. I always fantasise: if our body is 70% water, then you should be able to feel the patterns you see in the installation and which are generated by the soundwaves travelling through water. Theoretically those patterns could be happening in our bodily fluids too. It's a bit of a crazy idea of course, as if we could feel these cymatic patterns. But it is a nice fantasy.

AA Does the material the platforms are made of make a difference? Does the thickness of the material affect how soundwaves travel through the wood?

YU Yes, it matters. For the waves to travel as I want, the wood should be plywood. And also it makes a difference if there's a mattress or not. Sound travels much faster through metal than through wood. Metal resonates much quicker. The same is true for how the soundwaves travel though liquids. Soundwaves behave differently in denser fluids; floating a layer of oil on top makes a difference. Now I use water. You feel the soundwaves in the wood you lie on; you feel the frequencies rising and falling. The wood itself doesn't sound in ~~*Kulunka*~~, you only perceive the sound when you touch it. The same for the water: you don't hear those soundwaves, you can only see them. That's a conscious decision. You hear but cannot touch or see the external sound; you can see the visualised sound but cannot touch or hear it; and you cannot see nor hear the tactile sound, you can only feel it.

AA What is the artistic context or tradition that you feel close to?

YU Of course my work relates to cymatics, and all the artists that use cymatics, from Chladni to Hans Jenny to TeZ. The link between image and sound and the visual music scene are very important for me. A lot of people work with tactile sound. The phenomena of oto-acoustic emissions and Maryanne Amacher's work is another strand. None of this is really a tradition. Generally my work relates to art that is focused on experience that is focused on effects that your body produces itself, like flicker, which makes your retina produce patterns that you see. The idea that your body is part of the performance and not outside it, is of central importance. If you divided music into programmatic music and pure sound, then I fall into the category of pure sound. Pure, abstract sound that refer to nothing but sound. Pure sound is somehow more direct, and in that sense comes closer to the real meaning of sound, and its experience. If you play improvised music, you feel this directly.

BLACK AND WHITE

Simon Ings

Simon Ings spins together a few strands from the rich history of Soviet science, relates how an Arab scientist found out how the eye works, and criticises the belief that *techne* will free us of the constraints of Time, Space, and the Body.

Vladimir Lenin plays chess with Alexander Bogdanov during a visit to Maxim Gorky, 23–30 April 1908, Capri, Italy.

I

This photograph of a chess game was taken in April 1908 on the island of Capri.

The spectator is Maxim Gorky, and for months he's been trying to get these players to talk to each other again.

The one on the left is Aleksandr Bogdanov – a science fiction writer, a pioneer of Soviet blood transfusion, and one of the more illustrious nearly-rans in the race to cybernetics.

The player on the right is Vladimir Lenin, who needs no introduction from me.

It looks in the photograph as though he's yawning. He isn't. He is shouting. Bogdanov looks as though he studying the game. He isn't; he's getting ready to bolt. Look at how he's sitting in that chair. Or not sitting. In his mind he's half-way to the harbour already, return ferry ticket mulched in his sweaty fist. There is no ending this argument. There is no healing this rift. In Finland these two lived out of each other's pockets, but they're done now.

'When [he] began to quarrel with Bogdanov on the issue of *empiriomonism*, we threw up our hands and decided Lenin had gone slightly out of his mind', one contemporary memoirist wrote Empiriomonism means 'judging the world by the evidence of one's senses'.

Bogdanov was big on the senses, on the way we interpret the world through them, and on how a revolution – to be truly revolutionary – must also be a *sensual* revolution. He set up Proletkult once the Bolsheviks were in power. A spectacular rolling arts festival tasked with creating a new, proletarian culture. It was so successful, Lenin disembowelled it.

The political threat Proletkult represented must have been minor. Most likely, Lenin just hated it. He hated Bogdanov's thinking. He hated the idea of 'interpretation'. The way Lenin saw it, if you have to interpret the world in order to experience it, then you have to be agnostic about what it is you're experiencing. The world seems to be one thing – then again, with time and experience, it may turn out to be another. And we all know where that lands us, don't we, O children of the revolution? Agnosticism leads to subjectivism, leads to solipsism, leads to fideism. To God, in other words, or at any rate the possibility of God.

'Fuck that', says Lenin.

And if you think he didn't resort to that kind of language, you haven't read his *Materialism and Empiriocriticism* of 1909 – a shoo-in for one of the most downright offensive books ever written. It's based on his letters to Bogdanov: letters so rude, Bogdanov told him that they had better be treated as 'unwritten, undispatched and unread' if the two were ever to speak to each other again.

Lenin's position is as clear as it is stupid: he holds to a primitive copy theory of knowledge whereby our sensations are treated as 'photographs, images, mirror reflections of things'. 'Matter', Lenin explains, 'is a philosophical category which is given to man by his sensations, and which is copied, photographed and reflected by our sensations, while existing independently of them'.[1]

Lenin is throwing away two-and-a-half thousand years of intellectual endeavour here; and in the space of little more than a decade, his thinking is going to get the best minds of his generation killed.

II

It's five hundred years before the birth of Christ and you have no idea how sensations are received by the body; you have no idea how you know what you know; radiation isn't even a mystery to you, you simply haven't thought of it yet; and light is not a particle, not a wave, not even a ray – in fact, you haven't a clue what it is, beyond the fact that it's there in the day and gone in the night unless you light a match (only you haven't any matches).

What would your theory of perception look like? If you were smart, you might end up with atomism. Atomism, a philosophical school that started with Leucippus around the first half of the fifth century BC, says that everything is a thing, and things are made up of other things. As a theory of physics it's pretty dull, but as a theory of perception it's staggeringly good because it explains why we know what things are at a glance, even though we may not have seen that particular thing before. Everything is a thing, and every thing throws off atom-thin shells – *eidola* – and these, entering the eye like so many picture postcards, tell us what things are.

This is the sort of world Lenin lives in.

But it's no use: *eidola* don't make much physical sense – they get into the eye *how*? And the moment we start investigating matter seriously, dividing the world into elements, we have to let go of that sort of handwaving.

Fast-forward more than half a millennium.

1. V. I. Lenin, 'Materialism and Empirio-Criticism', in *Collected Works*, vol. 14, p. 130.

Caliph Al-Hakim, in true Mikado style, honed his homicidal cruelty on dogs before working his way up to people. Now and again he would ban vegetables.

Abū Alī al-Hasan ibn al-Hasan ibn al-Haytham was a bored forty-year-old civil servant in al-Haytham's administration. Around the turn of the first millennium AD, al-Haytham decided he would borrow some money from the Caliph and go build the Aswan dam. When that failed, al-Haythem faced summary execution for wasting his boss's cash. To save his neck he feigned madness. He retired to his house, blocked up his windows, and spent twelve years working out the lawful mechanics of light.

Al-Haytham founded the science of optics. And in doing that, he showed how vision needs no divine spark, no 'seeing ray', no magical crystal – that, in order to see, all that's necessary is that light enters the eyeball. Images will be focused on a wall within the cavity – and that's the end of story. Almost.

True, it took a while to find the wall in the eye. (Was it the lens? Or was it the back of the eye – the retina?) More troubling than the anatomy, though, was that image.

Focused through a narrow aperture it was, as any schoolchild will tell you, upside-down.

The trouble with an eye that sees upside down is it requires the brain to turn things the right way up. The brain cannot just apprehend what is out there – it has to manipulate the information it receives and then it has to re-present it.

But to whom, exactly, is this right-way-round image being represented? Is there a screen in the brain, and a watcher, watching it?

Al-Haytham and his successors winced away from the idea that eyes received inverted images for the very good reason that this simple optical quirk, in order to work, would require a whole new philosophy of mind – a view of perception that would drive a wedge between the world itself and the apprehending mind.

If everything we see is manipulated before we see it, how do we know that anything is true? Suddenly, the world is split in two: there is the world we sense – and there is the world represented by the senses. If everything we sense is a representation of what's really out there, then – well – what's really out there?

We don't know. We can't know – any more than I can know, from looking at the icons on my computer screen, exactly what is going on in the silver box under my fingers. I can control the box, as much as it will let me. I can drag files into a wastebasket. I can shuffle files from one folder to another. I can draw pictures. I can type words, and get them back again at the touch of a button. But I can't understand what's really going on inside this box of tricks, because the icons I click and drag need not in any way resemble what's really going on inside the box.

This vision of the world reduces all philosophy and science to a sort of user's manual – a description of how we interact with the world, which says nothing whatsoever about the way the world really works. It's a predicament which Donald Hoffman, an expert in computer vision, explored with unusual candour in his book *Visual Intelligence*:

> Neither biology nor quantum theory dictates the nature of the relational realm. Nor does any other science. Each studies certain phenomena, and describes these by precise theories. In no case do the phenomena or the theories dictate the nature of the relational realm. We might hope that the theories of science will converge to a true theory of the relational realm. This is the hope of scientific realism. But it's a hope as yet unrealised, and a hope that cannot be proved true.[2]

There are two possible wrong responses to this tragi-comic bind. One is to worship some sort of beneficent trickster God who turns the slides the right way up in your head before you see them.

Fuck that, as Lenin would say.

The other wrong response is Lenin's – to dismiss the problem out of hand as though it didn't matter. If you do this, you can no longer explore the one thing you know for sure about the universe – the fact that you experience it.

> For only the mechanically organised has reality, strength and permanence, mechanism alone is reliable; only the 'collective man', freed from the evil of the soul, mechanically united by external interests with all others, is strong. To him alone belongs the empire of the future; only he will be able to reign therein 'in the millennium [3]

2. Donald Hoffman, *Visual Intelligence: How We Create What We See,* New York: Norton 1998, p. 199.

3. René Fueloep-Miller, *The Mind and Face of Bolshevism: An Examination of Cultural Life in Soviet Russia*, New York: Harper & Row, 1965 (1926), p. 3.

III

If you think the universe is just there – a thing to be dealt with – then there is really no point trying to distinguish between science and engineering. They really are the same thing. And this is important: if the world is an engineering problem, then, when it fails to deliver on your promises, it's the engineers who are at fault.

Lenin's intellectual and political successor Joseph Stalin treated the whole of nature as though it were a machine in need of repair. His dachas had large greenhouses so he could walk straight from his bedroom into a collection of exotic plants. He was fascinated by the idea that it might be possible to alter the nature of plants. It was his only hobby. His only exercise. He had ambitious plans for lemons.

At a jubilee to celebrate the fiftieth birthday of Trofim Lysenko, the charlatan who destroyed Soviet genetics, Stalin handed that appalling fraud the Order of Lenin and the keys to the 'Great Stalin Plan for the Transformation of Nature'. He wanted to plant forest belts, to reverse the course of five Siberian rivers, to achieve heaven on Earth.

In 1957 Marcel Prenant, a scientist and a committed communist, toppled inadvertently into this Narnia when he interviewed Lysenko for a French newspaper:

> I allowed myself to put a question to him: 'I admit that young trees should be planted in a cluster; they may thus be better protected at first; but is it not necessary to remove some of them after a few years?' 'No', replied Lysenko explaining: 'They will sacrifice themselves for one'. 'Do you mean', I replied, 'that one will turn out to be stronger and the others will weaken or perish?' 'No', he repeated, 'They will sacrifice themselves for the good of the species', and he entered into a long and very hazy discourse, completely overwhelming me with a 'materialistic' explanation which would have been acceptable to Bernardin St Pierre, and which was very close to a belief in Divine Providence.[4]

Lysenko is the last generally remembered representative of that generation who wanted to be scientists but didn't have the patience. Bad workmen, they blamed their tools. Bloody botanists. Bloody

4. Quoted in Zhores A. Medvedev, *The Rise and Fall of T.D. Lysenko.* Translated by Michael I. Lerner, New York: Columbia University Press, 1969.

geneticists. Bloody histologists. Around half the scientists and engineers in the Soviet Union in the 1920s were eventually arrested. After sunspot development research was judged un-Marxist, twenty-seven astronomers disappeared between 1936 and 1938. The Meteorological Office was violently purged as early as 1933 for failing to predict weather harmful to crops. Long after the Second World War, some of the state's most eminent scientists and engineers worked in prison laboratories.

The rest became shockworkers on collective farms, were brutalised, reduced to a rabble of toadies and sneaks, all rant and cant and rage, each and every one stabbing their neighbour in the back in the struggle for tenure, denouncing each other, staging honour courts, every month writing their passive-aggressive letters of resignation, pleas to patrons for assistance against the forces of bourgeois idealism, anonymous accusations of toadying to the West.

'Down with formalist Mendelist-Morganism!' 'Down with the anti-grasslanders!' Children of the Great Terror, they'd drunk in its methods with their milk, and now they played them for stakes, talked up every move as though it were a military operation: 'Action on the Agronomic'.

And so, with all distinction lost between science and engineering, the myth arose – the old, deadly, unputdownable myth: that everything is malleable. Spin your wheel and stick in your thumbs: the living world is clay! Pines will turn to firs, sunflowers to zinnias. Animal cells will turn into plant cells. Plants into animals! Cells from soup! 'How can there be hereditary diseases in a socialist society?' From the nonliving will come the living.

In May 1950, the seventy-seven-year-old biologist Olga Lepeshinskaya received the Stalin Prize for filming living cells emerging from non-cellular materials. Actually, she had filmed the death and decomposition of cells, then projected these films reversed. Later she announced to the Academic Council of the Institute of Morphology that soda baths could rejuvenate the old and preserve the youth of the young. A couple of weeks later Moscow completely sold out of baking soda.

The trouble with this crowd – Lysenko, Vilyams, Kol, Lepeshinskaya, their sponsor Joseph Stalin and the whole lot of them, from Marx all the way up to Krushchev, is that they were fans. They loved science. They worshipped it. Glamourised it. Aspired to it. But like fans everywhere, deep down they resented what they thought they revered. They were like children, only without a child's charm, and in their most secret places, they longed to wield a rod of iron over their adopted gods.

IV

Such people have not gone away. They walk among us. They are our friends, our colleagues, in many cases, our peers. They write books for MIT Press and deliver TED talks. Should we be afraid? Probably not. The kind of evil and insanity you can squeeze from these people has to be socially constructed. No one, round here, right now, so far as we know, is putting a gun to anyone's head and simultaneously handing them control of the entire science base.

But the impulse survives. The belief that *techne* will free us of the constraints of Time, Space, and the Body – the burden, in other words, of being alive. The impatience. The fond hope. The tendency to ignore the hard parts of science, and treat the world as a big engineering problem, blaming the engineers when it fails to deliver. Ray Kurzweil, Eric Drexler, Cory Doctorow, Rachel Armstrong, Charles Stross, Gerard K. O'Neill: these people are an accident of history away from being dictators, monsters, killers.

The war correspondent Eric Sevareid once said, 'The chief cause of problems is solutions'. Which goes some way to pointing out why today's anti-clerical lobby, led by men of talent like Richard Dawkins, gives so many of us the chills. It is not that Dawkins is wrong. It is certainly not that he is rude (fuck that). It is that he concentrates on just half of the necessary argument. All anthropocentric explanations of the world are deadly – the ones that subscribe everything to mystery, yes, but also the ones who deny that any mystery exists.

The world is unknowable. It's just not entirely unknowable. Scientists understand this. They embrace the dark, they're tantalised by it, they get off on being radically decentered. They are, whether they like it or not, whether we like it or not, revolutionaries.

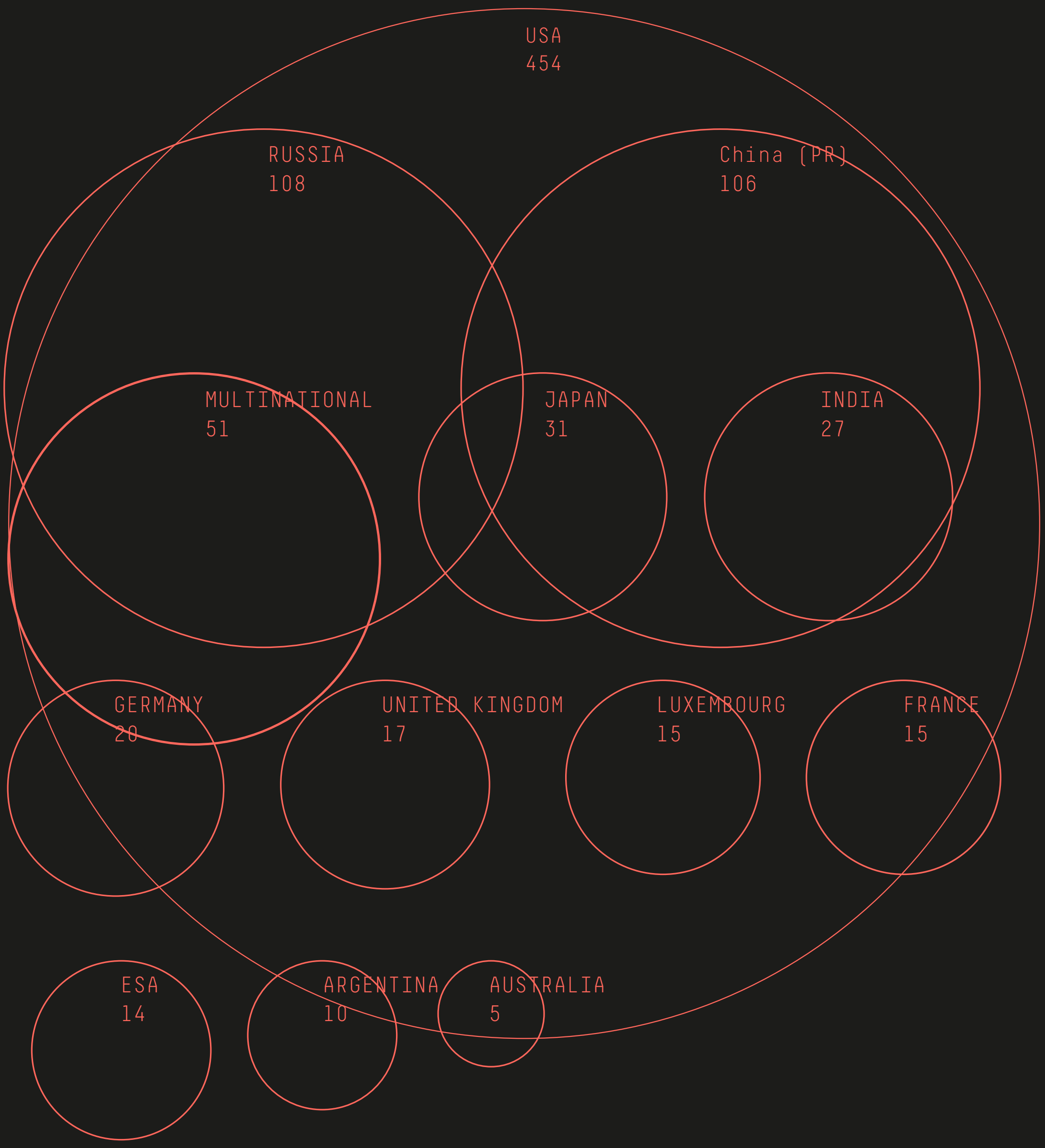
And that is why, every now and then, they get shot.

	Current Official Name of Satellite	Operator/Owner	Country of Operator/Owner	Users (C - Commercial, G - Government, Civ - Civil, M - Military)	Purpose	Class of Orbit	Launch Mass (kg.)	Year
361	Cosmos 2458	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2009
362	Cosmos 2461	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2010
363	Cosmos 2464	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2010
364	Cosmos 2465	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2010
365	Cosmos 2466	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2010
366	Cosmos 2474	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2011
367	Cosmos 2476	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2011
368	Cosmos 2477	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2011
369	Cosmos 2475	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2011
370	Cosmos 2478	Ministry of Defense	Russia	M/C	Navigation	MEO	1,415	2011
371	GOCE	ESA	ESA	G	Earth Science	LEO	1,100	2009
372	GOES-12	NOAA	USA	G	Earth Science	GEO	2,105	2001
373	GOES-13	NOAA	USA	G	Earth Science	GEO	3,200	2006
374	GOES-14	NOAA	USA	G	Earth Science	GEO	3,200	2009
375	GOES-15	NOAA	USA	G	Earth Science	GEO	3,175	2010
376	GOES-3	University of Miami,RSMAS	USA	Civ	Communications	GEO	627	1978
377	Gonets D1-1	Gonets Satcom	Russia	C/M	Communications	LEO	240	1996
378	Gonets D1-2	Gonets Satcom	Russia	C/G	Communications	LEO	240	1996
379	Gonets D1-3	Gonets Satcom	Russia	C/G	Communications	LEO	240	1996
380	Gonets D1-4	Gonets Satcom	Russia	C/G	Communications	LEO	240	1997
381	Gonets D1-5	Gonets Satcom	Russia	C/G	Communications	LEO	240	1997
382	Gonets D1-6	Gonets Satcom	Russia	C/G	Communications	LEO	240	1997
383	Gonets D1-7	Gonets Satcom	Russia	C/G	Communications	LEO	240	2001
384	Gonets D1-9	Gonets Satcom	Russia	C/G	Communications	LEO	240	2001
385	Gonets M-13	Gonets Satcom	Russia	C/G	Communications	LEO	270	2012
386	Gonets M-15	Gonets Satcom	Russia	C/G	Communications	LEO	270	2012
387	Gonets M-5	Gonets Satcom	Russia	C/G	Communications	LEO	270	2010
388	Grace 1	GFZ/University of Texas	Germany/USA	Civ	Earth Science	LEO	480	2002
389	Grace 2	GFZ/University of Texas	Germany/USA	Civ	Earth Science	LEO	480	2002
390	Ibuki	JAXA	Japan	Civ	Earth Science	LEO	1,750	2009
391	GSAT-10	ISRO	India	G	Communicatons	GEO	3,400	2012
392	GSAT-12	ISRO	India	G	Communications	GEO	1,410	2011
393	GSAT-2	ISRO	India	G	Communications	GEO	1,825	2003
394	GSAT-8	ISRO	India	G	Communications	GEO	3,093	2011
395	Haiyang 1B	State Oceanic Administration	China (PR)	G	Meteorology	LEO	500	2007
396	Haiyang 2A	State Oceanic Administration	China (PR)	G	Meteorology	LEO	1,500	2011

396

Optical reconnaissance: independent military intelligence capability for the EU

397	HAMSat	ISRO	India	G/C	Communications	LEO	43	2005
398	Helios 2A	CNES/DGA	FR/IT/BE/SP/GR	M	Reconnaissance	LEO	4,200	2004
399	Helios 2B	CNES/DGA	FR/IT/BE/SP/GR	M	Reconnaissance	LEO	4,200	2009
400	HellasSat 2	Hellas-Sat Consortium Ltd.	Greece	C	Communications	GEO	3,300	2003
401	RHESSI	UC Berkeley/NASA	USA	G/C	Astrophysics	LEO	293	2002
402	Hinode	NASA	Multinational	G	Solar Physics	LEO	700	2006
403	Hispasat 1C	Hispasat	Spain	C/G/M	Communications	GEO	3,112	2000
404	Hispasat 1D	Hispasat	Spain	C/G/M	Communications	GEO	3,288	2002
405	Hispasat 1E	Hispasat	Spain	C	Communications	GEO	5,320	2010
406	HJ-1A	NRSCC	China (PR)	G	Remote Sensing	LEO	470	2008
407	HJ-1B	NRSCC	China (PR)	G	Remote Sensing	LEO	470	2008
408	HJ-1C	National Committee	China (PR)	G	Remote Sensing	LEO	890	2012



SPACE TERRITORY

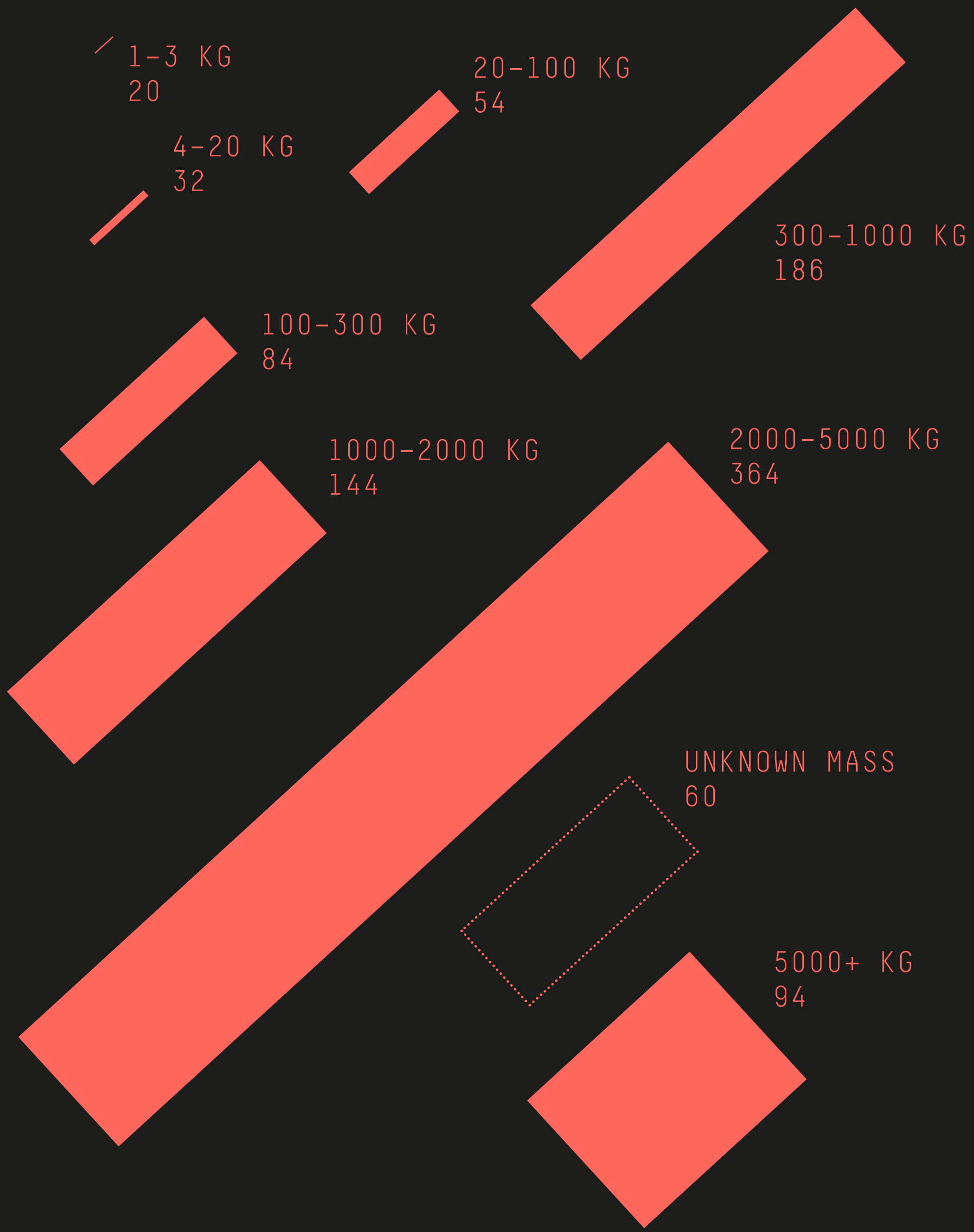
number of orbiting satellites

409	Horizons 2	Intelsat, JSAT	USA/Japan	C	Communications	GEO	2,300	2007
410	Horyu-2	KIT	Japan	Civ	Tech Development	LEO	7	2012
411	Hot Bird 10	EUTELSAT	Multinational	C	Communications	GEO	4,892	2009
412	Hot Bird 6	EUTELSAT	Multinational	C	Communications	GEO	3,800	2002
413	Hot Bird 8	EUTELSAT	Multinational	C	Communications	GEO	4,900	2006
414	Hot Bird 9	EUTELSAT	Multinational	C	Communications	GEO	4,880	2008
415	Hubble	European Space Agency/NASA	ESA/USA	G	Astrophysics	LEO	11,110	1990
416	HYLAS 1	Avanti Communications, PLC	UK	C	Communications	GEO	2,242	2010
417	HYLAS 2	Avanti Communications, PLC	UK	C	Communications	GEO	3,311	2012
418	IGS-1A	CSIC	Japan	G	Reconnaissance	LEO	850	2003
419	IGS-3A	CSIC	Japan	G	Reconnaissance	LEO	850	2006
420	IGS-5A	CSIC	Japan	G	Reconnaissance	LEO	1,600	2009
421	IGS-6A	CSIC	Japan	G	Reconnaissance	LEO	1,600	2011
422	IGS-7A	CSIC	Japan	G	Reconnaissance	LEO	1,600	2011
423	Ikonos-2	GeoEye	USA	C	Remote Sensing	LEO	726	1999
424	USA 184	NRO	USA	M	Surveillance	Ell	4,000	2006
425	USA 200	NRO	USA	M	Surveillance	Ell	4,200	2008
426	IMS 1	ISRO	India	G	Remote Sensing	LEO	83	2008
427	INMARSAT 2F1	INMARSAT, Ltd.	United Kingdom	C	Communications	GEO		1990
428	INMARSAT 3F1	INMARSAT, Ltd.	United Kingdom	C	Communications	GEO	2,064	1996
429	INMARSAT 3F2	INMARSAT, Ltd.	United Kingdom	C	Communications	GEO	2,070	1996
430	INMARSAT 3F3	INMARSAT, Ltd.	United Kingdom	C	Communications	GEO	2,074	1996
431	INMARSAT 3F4	INMARSAT, Ltd.	United Kingdom	C	Communications	GEO	2,066	1997
432	INMARSAT 3F5	INMARSAT, Ltd.	United Kingdom	C	Communications	GEO	2,000	1998
433	INMARSAT 4F1	INMARSAT, Ltd.	United Kingdom	C	Communications	GEO	5,959	2005
434	INMARSAT 4F2	INMARSAT, Ltd.	United Kingdom	C	Communications	GEO	5,458	2005
435	INMARSAT 4F3	INMARSAT, Ltd.	United Kingdom	C	Communications	GEO	5,960	2008
436	INSAT 3A	ISRO	India	G	Communications	GEO	2,950	2003
437	INSAT 3C	ISRO	India	G	Communications	GEO	2,750	2002
438	INSAT 3E	ISRO	India	G	Earth Science	GEO	2,750	2003
439	INSAT 4A	ISRO	India	G	Communications	GEO	3,100	2005
440	INSAT 4B	ISRO	India	G	Communications	GEO	3,028	2007
441	INSAT 4CR	ISRO	India	G	Communications	GEO	2,130	2007
442	INTErnational	INTEGRAL/ESOC/NASA/Russia	ESA/USA/Russia	G	Space Physics	Ell	4,000	2002
443	Intelsat 10	Intelsat, Ltd.	USA	C	Communications	GEO	3,739	2001
444	Intelsat10-02	Intelsat, Ltd.	USA	C	Communications	GEO	5,576	2004
445	Intelsat 11	PanAmSat (Intelsat, Ltd.)	USA	C	Communications	GEO	2,491	2007
446	Intelsat 14	Intelsat, Ltd.	USA	C	Communications	GEO	5,613	2009
447	Intelsat 15	Intelsat, Ltd./JSAT Corp.	USA	C	Communications	GEO	2,550	2009
448	Intelsat 16	Intelsat, Ltd.	USA	C	Communications	GEO	2,450	2010
449	Intelsat 17	Intelsat, Ltd.	USA	C	Communications	GEO	5,540	2010
450	Intelsat 18	Intelsat, Ltd.	USA	C	Communications	GEO	3,2001	2011
451	Intelsat 18	Intelsat, Ltd.	USA	C	Communications	GEO	3,2001	2011
452	Intelsat 19	Intelsat, Ltd.	USA	C	Communications	GEO	5,600	2012
453	Intelsat 1R	PanAmSat (Intelsat, Ltd.)	USA	C	Communications	GEO	4,793	2000
454	Intelsat 20	Intelsat, Ltd.	USA	C	Communications	GEO	6,094	2012
455	Intelsat 21	Intelsat, Ltd.	USA	C	Communications	GEO	5,984	2012
456	Intelsat 22	Intelsat, Ltd.	USA	C	Communications	GEO	6,199	2012
457	Intelsat 23	Intelsat, Ltd.	USA	C	Communications	GEO	3,200	2012
458	Intelsat 25	Intelsat, Ltd.	USA	C	Communications	GEO	4,100	2008
459	JCSat R	Intelsat, Ltd.	USA	C	Communications	GEO	3,124	1997
460	Intelsat 5	Intelsat, Ltd.	USA	C	Communications	GEO	2,730	1997
461	Intelsat 603	Intelsat, Ltd./SES	USA	C	Communications	GEO	4,200	1990
462	Intelsat 7	PanAmSat (Intelsat, Ltd.)	USA	C	Communications	GEO	3,833	1998
463	Intelsat 701	Intelsat, Ltd.	USA	C	Communications	GEO	3,642	1993
464	Intelsat 702	Intelsat, Ltd.	USA	C	Communications	GEO	3,642	1994
465	Intelsat 706	Intelsat, Ltd.	USA	C	Communications	GEO	3,653	1995
466	Intelsat 709	Intelsat, Ltd.	USA	C	Communications	GEO	4,180	1996
467	Intelsat 8	PanAmSat (Intelsat, Ltd.)	USA	C	Communications	GEO	3,592	1998
468	Intelsat 801	Intelsat, Ltd.	USA	C	Communications	GEO	3,447	1997
469	Intelsat 805	Intelsat, Ltd.	USA	C	Communications	GEO	3,420	1998
470	Intelsat 9	PanAmSat (Intelsat, Ltd.)	USA	C	Communications	GEO	3,659	2000
471	Intelsat 901	Intelsat, Ltd.	USA	C	Communications	GEO	4,723	2001
472	Intelsat 902	Intelsat, Ltd.	USA	C	Communications	GEO	4,723	2001
473	Intelsat 903	Intelsat, Ltd.	USA	C	Communications	GEO	4,723	2002
474	Intelsat 904	Intelsat, Ltd.	USA	C	Communications	GEO	4,680	2002
475	Intelsat 905	Intelsat, Ltd.	USA	C	Communications	GEO	4,723	2002
476	Intelsat 906	Intelsat, Ltd.	USA	C	Communications	GEO	4,723	2002
477	Intelsat 907	Intelsat, Ltd.	USA	C	Communications	GEO	4,685	2003
478	IntelsatAPR2	Intelsat, Ltd.	USA	C	Communications	GEO	2,550	1999
479	I.sat NewDawn	Intelsat, Ltd.	USA	C	Communications	GEO	3,000	2011
480	Int. Station	NASA/Multinational	Multinational	G	Science	LEO		1998
481	IBExplorer	NASA/Goddard Center	USA	G	Space Physics	Ell	462	2008
482	Iridium 10	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997

483	Iridium 11A	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
484	Iridium 12	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
485	Iridium 13	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
486	Iridium 14A	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1999
487	Iridium 15	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
488	Iridium 18	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
489	Iridium 19	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
490	Iridium 20A	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
491	Iridium 21A	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1999
492	Iridium 22	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
493	Iridium 23	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
494	Iridium 25	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
495	Iridium 29	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
496	Iridium 3	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
497	Iridium 30	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
498	Iridium 31	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
499	Iridium 32	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
500	Iridium 34	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
501	Iridium 35	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
502	Iridium 37	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
503	Iridium 39	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
504	Iridium 40	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
505	Iridium 41	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
506	Iridium 42	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
507	Iridium 43	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
508	Iridium 45	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
509	Iridium 47	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
510	Iridium 49	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
511	Iridium 5	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
512	Iridium 50	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
513	Iridium 51	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
514	Iridium 52	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
515	Iridium 53	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
516	Iridium 54	Iridium Satellite LLC	USA	G/C	Communications	LEO		1998
517	Iridium 55	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
518	Iridium 56	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
519	Iridium 57	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
520	Iridium 58	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
521	Iridium 59	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
522	Iridium 6	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
523	Iridium 60	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
524	Iridium 61	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
525	Iridium 62	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
526	Iridium 63	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
527	Iridium 64	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
528	Iridium 65	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
529	Iridium 66	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
530	Iridium 67	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
531	Iridium 68	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
532	Iridium 7	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
533	Iridium 70	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
534	Iridium 72	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
535	Iridium 74	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
536	Iridium 75	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
537	Iridium 76	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
538	Iridium 77	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
539	Iridium 8	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1997
540	Iridium 80	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
541	Iridium 81	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
542	Iridium 82	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
543	Iridium 83	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
544	Iridium 84	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
545	Iridium 86	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	1998
546	Iridium 90	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	2002
547	Iridium 91	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	2002
548	Iridium 94	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	2002
549	Iridium 95	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	2002
550	Iridium 96	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	2002
551	Iridium 97	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	2002
552	Iridium 98	Iridium Satellite LLC	USA	G/C	Communications	LEO	689	2002
553	IRS-P6	ISRO	India	G	Remote sensing	LEO	1,360	2003
554	ITU-pSAT1	ITU	Turkey	Civ	Tech Development	LEO	1	2009
555	Jason 1	NASA/CNES	USA/France	G	Earth Science	LEO	470	2001
556	Jason 2	NASA/CNES/NOAA/EUMETSAT	USA/France	G	Earth Science	LEO	553	2008

557	JCSat 10	Sky Perfect JSAT	Japan	C	Communications	GEO	4,400	2006
558	JCSat 110	Sky Perfect JSAT	Japan	C	Communications	GEO	3,531	2000
559	JCSat 13	Sky Perfect JSAT	Japan	C	Communications	GEO	4,500	2012
560	JCSat 1B	Sky Perfect JSAT	Japan	C	Communications	GEO	2,982	1997
561	JCSat 2A	Sky Perfect JSAT	Japan	C	Communications	GEO	2,500	2002
562	JCSat 4A	Sky Perfect JSAT	Japan	C	Communications	GEO	2,900	1999
563	JCSat 9	Sky Perfect JSAT	Japan	C	Communications	GEO	4,400	2006
564	JCSat RA	Sky Perfect JSAT	Japan	C	Communications	GEO	4,000	2009
565	Jugnu	Indian Inst TechKanpur	India	Civ	Earth Observation	LEO	3	2011
566	Kalpana-1	ISRO	India	G	Earth Science	GEO	1,060	2002
567	KA-SAT	EUTELSAT	Multinational	C	Communications	GEO	6,150	2010
568	KazSat-2	JSC KazSat	Kazakhstan	C	Communications	GEO	1,300	2011
569	USA 144	NRO	USA	M	Reconnaissance	LEO	18,000	1999
570	USA 161	NRO	USA	M	Reconnaissance	LEO	18,000	2001
571	USA 186	NRO	USA	M	Reconnaissance	LEO	18,000	2005
572	USA 224	NRO	USA	M	Reconnaissance	LEO	18,000	2011
573	ETS-8	NICT	Japan	G	Tech Development	GEO	5,800	2006
574	Kizuna	JAXA	Japan	G	Tech Development	GEO	4,850	2008
575	KKS-1	Tokyo Metropolitan College	Japan	Civ	Tech Development	LEO	3	2009
576	Kompsat-2	KARI	South Korea	G/C	Earth Observation	LEO	800	2006
577	Kompsat-3	KARI	South Korea	G/C	Earth Observation	LEO	1,000	2012
578	Koreasat 5	KT Corporation/ADD	South Korea	M/C	Communications	GEO	4,450	2006
579	Koreasat 6	KT Corporation	South Korea	C	Communications	GEO	2,850	2010
580	USA 133	NRO	USA	M	Surveillance	LEO	14,500	1997
581	USA 152	NRO	USA	M	Surveillance	LEO	14,500	2000
582	USA 182	NRO	USA	M	Surveillance	LEO	14,500	2005
583	Landsat 7	NASA/US Geological Survey	USA	G	Earth Science	LEO	2,744	1999
584	LAPAN-Tubsat	LAPAN	Indonesia	G	Tech Development	LEO	60	2007
585	LatinSat A	Aprize Satellites Argentina	Argentina	C	Communications	LEO		2002
586	LatinSat B	Aprize Satellites Argentina	Argentina	C	Communications	LEO		2002
587	Leasat 5	US DoD/Royal Australian Navy	USA/Australia	M	Communications	GEO	3,400	1990
588	Cosmos 2455	M of Defense	Russia	M	Reconnaissance	LEO	5,000	2009
589	Luch 5A	Russian Federal Space Agency	Russia	G	Communications	GEO	950	2011
590	Luch 5B	Russian Federal Space Agency	Russia	Go	Communications	GEO	1,282	2012
591	Maroc Tubsat	CTRS Morocco/Inst für Rf	Morocco/Germany	G	Tech Development	LEO	47	2001
592	MaSat 1	Budapest University	Hungary	Civ	Tech Development	LEO	1	2012
593	M-Cubed	University of Michigan	USA	Civ	Tech Development	LEO	2	2011
594	Measat 2	MEASAT Satellite Systems Sdn.	Malaysia	C	Communications	GEO	1,450	1996
595	Measat 3	MEASAT Satellite Systems Sdn.	Malaysia	C	Communications	GEO	4,900	2006
596	Measat 3A	MEASAT Satellite Systems Sdn.	Malaysia	C	Communications	GEO	2,417	2009
597	Megha-Trop	ISRO/CNES	India/France	Go	Earth Science	LEO	1,000	2011
598	USA 105	NRO/USAF	USA	M	Surveillance	GEO	8,000	1994
599	USA 118	NRO/USAF	USA	M	Surveillance	GEO	8,000	1996
600	Meridian-3	Military Space Forces (VKS)	Russia	M	Communications	Ell	2,500	2010
601	Meridian-4	Military Space Forces (VKS)	Russia	M	Communications	Ell	2,500	2011
602	Meridian-6	Military Space Forces (VKS)	Russia	M	Communications	Ell		2012
603	Meteor-M	ROSHYDROMET	Russia	G	Meteorology	LEO	2,700	2009
604	Meteosat 10	EUMETSAT	Multinational	G/C	Earth Science	GEO	2,000	2012
605	Meteosat 7	EUMETSAT	Multinational	G/C	Earth Science	GEO	696	1997
606	Meteosat 8	EUMETSAT	Multinational	G/C	Earth Science	GEO	2,000	2002
607	Meteosat 9	EUMETSAT	Multinational	G/C	Earth Science	GEO	2,000	2005
608	MetOp-A	ESA/EUMETSAT	Multinational	G/C	Earth Science	LEO	4,193	2006
609	MetOp-B	ESA/EUMETSAT	Multinational	G/C	Earth Science	LEO	4,085	2012
610	USA 99	US Air Force	USA	M	Communications	GEO	4,536	1994
611	USA 115	US Air Force	USA	M	Communications	GEO	4,536	1995
612	USA 157	US Air Force	USA	M	Communications	GEO	4,536	2001
613	USA 164	US Air Force	USA	M	Communications	GEO	4,536	2002
614	USA 169	US Air Force	USA	M	Communications	GEO	4,536	2003
615	MiR	Joint Stock Company	Russia	Civ	Earth Observation	LEO	65	2012
616	MKA-FKI-1	Lavochkin NPO	Russia	G	Remote Sensing	LEO	110	2012
617	Molniya 3-53	Military Space Forces (VKS)	Russia	M/C	Communications	Ell	1,600	2003
618	Molniya 1-92	Military Space Forces (VKS)	Russia	M/C	Communications	Ell	1,600	2003
619	MOST	Canadian Space Agency	Canada	G	Astrophysics	LEO	53	2003
620	Mozhayets 4	Mozhaisky Academy	Russia	Civ	Tech Development	LEO	64	2003
621	MSAT 1	Mobile Satellite Ventures	USA/Canada	C	Communications	GEO	2,850	1996
622	MSAT 2	Mobile Satellite Ventures	USA/Canada	C	Communications	GEO	2,850	1995
623	MTI	US Department of Energy	USA	G/M	Tech Development	LEO	587	2000
624	MTSAT-1R	Ministry of Transport	Japan	G	Navigation	GEO	2,900	2005
625	MTSAT-2	Meteorological Agency/MSC	Japan	G	Meteorology	GEO	2,900	2006
626	MUOS-1	DoD/US Navy	USA	M	Communications	GEO	6,804	2012
627	Nanosat-1	INTA	Spain	G	Communications	LEO	20	2004
628	Nanosat-1B	INTA	Spain	G	Tech Development	LEO	20	2009
629	NATO-4B	Ministry of Defense/EADS	United Kingdom	M	Communications	GEO	1,430	1993
630	USA 66	DoD/US Air Force	USA	M/C	Navigation	MEO	1,816	1990

631	USA 94	DoD/US Air Force	USA	M/C	Navigation	MEO	1,816	1993
632	USA 83	DoD/US Air Force	USA	M/C	Navigation	MEO	1,816	1992
633	USA 92	DoD/US Air Force	USA	M/C	Navigation	MEO	1,816	1993
634	USA 96	DoD/US Air Force	USA	M/C	Navigation	MEO	1,816	1993
635	USA 100	DoD/US Air Force	USA	M/C	Navigation	MEO	1,816	1994
636	USA 117	DoD/US Air Force	USA	M/C	Navigation	MEO	1,816	1996
637	USA 126	DoD/US Air Force	USA	M/C	Navigation	MEO	1,816	1996
638	USA 135	DoD/US Air Force	USA	M/C	Navigation	MEO	1,816	1997
639	USA 94	DoD/US Air Force	USA	M/C	Navigation	MEO	1,816	1993
640	USA 213	DoD/US Air Force	USA	M/C	Navigation	MEO	1,630	2010
641	USA 232	DoD/US Air Force	USA	M/C	Navigation	MEO	1,630	2011
642	USA 239	DoD/US Air Force	USA	M/C	Navigation	MEO	1,630	2012
643	USA 175	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	2003
644	USA 177	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	2004
645	USA 178	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	2004
646	USA 180	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	2004
647	USA 132	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	1997
648	USA 145	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	1999
649	USA 150	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	2000
650	USA 151	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	2000
651	USA 154	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	2000
652	USA 156	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	2001
653	USA 166	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	2003
654	USA 168	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	2003
655	USA 183	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	2005
656	USA 190	DoD/US Air Force	USA	M/C	Navigation	MEO	2,060	2006
657	USA 192	DoD/US Air Force	USA	M/C	Navigation	MEO	2,060	2006
658	USA 196	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	2007
659	USA 199	DoD/US Air Force	USA	M/C	Navigation	MEO	2,060	2007
660	USA 201	DoD/US Air Force	USA	M/C	Navigation	MEO	2,217	2008
661	USA 206	DoD/US Air Force	USA	M/C	Navigation	MEO	2,059	2009
662	NFIRE	Missile Defense Agency	USA	M	Tech Development	LEO	494	2007
663	NigComSat-1R	NigComSat	Nigeria	C	Communications	GEO	5,150	2011
664	NigeriaSat-2	NASRDA	Nigeria	G	Earth Observation	LEO	300	2011
665	Nigeriasat-X	NASRDA	Nigeria	G	Tech Development	LEO	100	/2011
666	Nilesat 101	Egyptian Radio and TV Union	Egypt	G	Communications	GEO	1,840	1998
667	Nilesat 102	Egyptian Radio and TV Union	Egypt	G	Communications	GEO	1,825	2000
668	Nilesat 201	Egyptian Radio and TV Union	Egypt	G	Communications	GEO	3,200	2010
669	Nimiq 1	Telesat Canada Ltd.	Canada	C	Communications	GEO	3,600	1999
670	Nimiq 2	Telesat Canada Ltd.	Canada	C	Communications	GEO	3,600	2002
671	Nimiq 4	Telesat Canada Ltd.	Canada	C	Communications	GEO	4,850	2008
672	Nimiq 5	Echostar Corporation	Canada	C	Communications	GEO	4,745	2009
673	Nimiq 6	Telesat Canada Ltd.	Canada	C	Communications	GEO	4,745	2012
674	NOAA-15	NOAA	USA	G	Earth Science	LEO	2,223	1998
675	NOAA-16	NOAA	USA	G	Earth Science	LEO	2,223	2000
676	NOAA-17	NOAA	USA	G	Meteorology	LEO	2,223	2002
677	NOAA-18	NOAA	USA	G	Meteorology	LEO	2,223	2005
678	NOAA-19	NOAA	USA	G	Meteorology	LEO	1,420	2009
679	NPP	NOAA/NASA	USA	G	Meteorology	LEO	2,128	2011
680	NSS-10	SES	Netherlands	C	Communications	GEO	5,396	2005
681	NSS-11	SES	Netherlands	C	Communications	GEO	3,582	2000
682	NSS-12	SES	Netherlands	C	Communications	GEO		2009
683	NSS-5	SES World Skies/Intelsat	Netherlands	C	Communications	GEO	3,412	1997
684	NSS-6	SES	Netherlands	C	Communications	GEO	4,575	2002
685	NSS-7	SES	Netherlands	C	Communications	GEO	4,500	2002
686	NSS-703	SES /Intelsat	Netherlands	C	Communications	GEO	3,642	1994
687	NSS-806	SES/Intelsat SES	Netherlands	C	Communications	GEO	3,720	1998
688	NSS-9	SES	Netherlands	C	Communications	GEO	2,238	2009
689	N-Star C	Sky Perfect JSAT Corporation	Japan	C	Communications	GEO	1,625	2002
690	NuSTAR	NASA	USA	G	Space Science	LEO	360	2012
691	USA 219	NASA-Ames/Stanford Uni	USA	Civ/G	Sci Research	LEO	6	2010
692	Oceansat-2	ISRO	India	G	Remote Sensing	LEO	960	2009
693	Odin	Swedish National Space Board	Sweden	G	Astrophysics	LEO	250	2001
694	Ofeq 5	Ministry of Defense	Israel	M	Reconnaissance	LEO	300	2002
695	Ofeq 7	Ministry of Defense	Israel	M	Reconnaissance	LEO	300	2007
696	Ofeq 9	Ministry of Defense	Israel	M	Reconnaissance	LEO	300	2010
697	Optus	Singapore Telecom	Australia	M/C	Communications	GEO	4,800	2003
698	Optus B3	Singapore Telecom	Australia	C	Communications	GEO	2,858	1994
699	Optus D1	Singapore Telecom	Australia	C	Communications	GEO	2,300	2006
700	Optus D2	Singapore Telecom	Australia	C	Communications	GEO	2,400	2007
701	Optus D3	Singapore Telecom	Australia	C	Communications	GEO	2,501	2009
702	ORBCOMM FM-10	ORBCOMM Inc.	USA	C	Communications	LEO	45	1997
703	ORBCOMM FM-11	ORBCOMM Inc.	USA	C	Communications	LEO	45	1997
704	ORBCOMM FM-12	ORBCOMM Inc.	USA	C	Communications	LEO	45	1997



LAUNCH MASS

orbiting satellites,
future debris

705	ORBCOMM FM-13	ORBCOMM Inc.	USA	C	Communications	LEO	45	1998
706	ORBCOMM FM-14	ORBCOMM Inc.	USA	C	Communications	LEO	45	1998
707	ORBCOMM FM-15	ORBCOMM Inc.	USA	C	Communications	LEO	45	1998
708	ORBCOMM FM-16	ORBCOMM Inc.	USA	C	Communications	LEO	45	1998
709	ORBCOMM FM-18	ORBCOMM Inc.	USA	C	Communications	LEO	45	1998
710	ORBCOMM FM-19	ORBCOMM Inc.	USA	C	Communications	LEO	45	1998
711	ORBCOMM FM-20	ORBCOMM Inc.	USA	C	Communications	LEO	45	1998
712	ORBCOMM FM-22	ORBCOMM Inc.	USA	C	Communications	LEO	45	1998
713	ORBCOMM FM-23	ORBCOMM Inc.	USA	C	Communications	LEO	45	1998
714	ORBCOMM FM-25	ORBCOMM Inc.	USA	C	Communications	LEO	45	1998
715	ORBCOMM FM-27	ORBCOMM Inc.	USA	C	Communications	LEO	45	1998
716	ORBCOMM FM-30	ORBCOMM Inc.	USA	C	Communications	LEO	45	1999
717	ORBCOMM FM-31	ORBCOMM Inc.	USA	C	Communications	LEO	45	1999
718	ORBCOMM FM-32	ORBCOMM Inc.	USA	C	Communications	LEO	45	1999
719	ORBCOMM FM-34	ORBCOMM Inc.	USA	C	Communications	LEO	45	1999
720	ORBCOMM FM-35	ORBCOMM Inc.	USA	C	Communications	LEO	45	1999
721	ORBCOMM FM-36	ORBCOMM Inc.	USA	C	Communications	LEO	45	1999
722	ORBCOMM FM-4	ORBCOMM Inc.	USA	C	Communications	LEO	45	1998
723	ORBCOMM FM-5	ORBCOMM Inc.	USA	C	Communications	LEO	45	1997
724	ORBCOMM FM-6	ORBCOMM Inc.	USA	C	Communications	LEO	45	1997
725	ORBCOMM FM-7	ORBCOMM Inc.	USA	C	Communications	LEO	45	1997

725

Reconaissance for US Central Command in Afghanistan and Central Asia.

726	ORBCOMM FM-8	ORBCOMM Inc.	USA	C	Communications	LEO	45	1997
727	ORBCOMM FM-9	ORBCOMM Inc.	USA	C	Communications	LEO	45	1997
728	USA 231	U.S. Air Force/ DoD	USA	M	Reconnaissance	LEO	434	2011
729	Ørsted	DMI	Denmark	G	Earth Science	LEO	61	1999
730	Paksat-1R	SUPARCO/PakSat International	Pakistan	G/C	Communications	GEO	5,120	2011
731	Palapa C2	PT Indosat	Indonesia	C	Communications	GEO	3,014	1996
732	Palapa D1	PT Indosat	Indonesia	C	Communications	GEO	4,100	2009
733	USA 207	Unknown US agency	USA	M	Communications	GEO		2009
734	LIDAR	PARASOL/CNES	France	G	Earth Science	LEO	120	2004
735	Cosmos 2389	Ministry of Defense	Russia	M	Navigation	LEO	825	2002
736	Cosmos 2398	Ministry of Defense	Russia	M	Navigation	LEO	820	2003
737	Cosmos 2361	Ministry of Defense	Russia	M	Navigation	LEO	795	1998
738	Cosmos 2366	Ministry of Defense	Russia	M	Navigation	LEO	795	1999
739	Cosmos 2378	Ministry of Defense	Russia	M	Navigation	LEO	825	2001
740	Cosmos 2407	Ministry of Defense	Russia	M	Navigation	LEO	825	2004
741	Cosmos 2414	Ministry of Defense	Russia	M	Navigation	LEO	825	2005
742	Cosmos 2429	Ministry of Defense	Russia	M	Navigation	LEO	810	2007
743	Cosmos 2454	Ministry of Defense	Russia	M	Navigation	LEO	810	2009
744	Cosmos 2463	Ministry of Defense	Russia	M	Navigation	LEO	820	2010
745	PCSat	US Naval Academy	USA	G	Tech Development	LEO	10	2001
746	Picard	CNES	France	G	Solar Physics	LEO	150	2010
747	Pléiades HR1	Ministry of Defense/CNES	AU/BE/SP/SE/FR/IT	G	Earth Observation	LEO	1,000	2011
748	Prism	University of Tokyo	Japan	Civ	Earth Observation	LEO	5	2009
749	Proba 1	ESA	ESA	G	Tech Demonstration	LEO	100	2001
750	Proba 2	ESA	ESA	G	Tech Demonstration	LEO	130	2009
751	QueztSat-1	SES World Skies SES	USA	C	Communications	GEO	5,514	2011
752	Quickbird 2	DigitalGlobe Corporation	USA	C	Earth Observation	LEO		2001
753	QZS-1	JAXA	Japan	G	Navigation	GEO	4,000	2010
754	Radarsat-1	Radarsat International	Canada	C	Earth Observation	LEO	2,924	1995
755	Radarsat-2	Radarsat International	Canada	C	Earth Observation	LEO	2,924	2007
756	Radio-ROSTO	RS3A Control Station	Russia	Civ	Amateur Radio	MEO		1994
757	Cosmos 2450	Ministry of Defense	Russia	M	Communications	GEO	2,400	2009
758	Cosmos 2434	Ministry of Defense	Russia	M	Communications	GEO	2,400	2007
759	Raduga 1-M2	Ministry of Defense	Russia	M	Communications	GEO	2,500	2010
760	USA 225	NRO	USA	M	Tech Development	LEO	350	2011
761	RapidEye-1	RapidEye AG	Germany	C	Earth Observation	LEO	175	2008
762	RapidEye-2	RapidEye AG	Germany	C	Earth Observation	LEO	175	2008
763	RapidEye-3	RapidEye AG	Germany	C	Earth Observation	LEO	175	2008

MODULATING NOISE

Interview with Gert-Jan Prins

Arie Altena

It's 31 October 2012, a Wednesday morning, and Gert-Jan Prins is in his studio on the Quellijnstraat in Amsterdam, talking about his work. He's standing at the workbench where he builds his small transmitters and receivers – there's a soldering iron, and resistors and little boxes filled with electronics. There's also a drum kit standing in the room – Prins has a background in drumming, and he played drums on the improvisation circuit for many years until his fascination for radio, noise and electronics gained the upper hand. Elsewhere in the studio there are all sorts of electronic equipment and a wall of analogue televisions that are used for performances by the Synchronator Orchestra, which had premiered two weeks earlier at the Kontraste Festival in Krems, Austria. Prins has deeply immersed himself in the phenomenon of noise, both as an artist and a musician, and his work makes electric space audible and palpable. He's on a quest to find the very essence of the electronic signal. In his frequent musical performances he plays his self-made circuits and uses the sound to create moving images generated by the Synchronator, which he developed with Bas van Koolwijk. 2008 saw the release of his *Break Before Make* album through Mego. His work also appears on the art circuit. An example is his *Cavity*, an electric space built from sheet copper at Onomatopee in Eindhoven, the Netherlands.

Arie Altena On 3 November 2012 you'll be presenting your work at De Player in Rotterdam, as part of the SESD [Sculptural Electronic Sound Discs] project. What did you make for it?

Gert-Jan Prins The SESD project was conceived by Peter Fengler and the other artists are Gijs Gieskes, Tom Verbruggen and Dennis de Bel. We're each going to make a record with integrated electronics. We're going to cast the records ourselves. On mine there's a five-minute track I made with one of my own little transmitters. And then I solder my circuits onto it – exactly the same kind of transmitter as the one I used to make the track on the record. You can tune your radio to the transmitter so you can mix in the sound of the radio with the sound of the record as you play it. It's quite possible that playing it on different record players will create different effects because the magnetic field of the record players motor might cause interference, for example. Some record players have solid metal turntables, while others are made entirely of plastic. So you can expand the sound to your own radio, thereby creating an extra layer.

AA It's the first time you're using the self-made circuit in this way. It's actually a component in a sound sculpture isn't it?

GJP Well of course I've thought before about making a series of the boxes I use and then selling them. There's been a trend over the last few years of makers selling their own custom-made electronics. Sometimes they're unique pieces, but other times they're produced as a series – like Bas van Koolwijk and I did with the Synchronator. The prototypes for the Synchronator were really beautiful, but we put them in a box so we could produce a series of them. The transmitter-receiver systems I build are purely about functionality. I arrange the components on a board, and it is what it is. It's all about functionality for me: it's got to make sound. There's no way I'd set them out differently on a board to make it look nicer. Of course I do like it that the battery I ordered for this transmitter looks a bit like a record player, but I ordered it because of its functionality, not its appearance.

AA Could you explain exactly what this transmitter consists of?

GJP There's a battery, a transistor, a few resistors and capacitators, a tuned circuit – a combination of coil and capacitator. It only lets through one specific frequency – in this case it's about 104 Mhz. The signal gets fed back by generating momentary negative resistance. The transistor actually functions as a kind of pump. The components have been selected so that this gorgeous feedback isn't impeded in any way. It works better if you've got a good solid area that functions as a negative, such as a big copper PCB. I had a different solution initially, but there were insurmountable technical problems when it came to using it with FM radio. I got all sorts of parasitic effects, and that's exactly what I don't want.

AA When you build these circuits, are you searching for a particular sound?

GJP On the one hand I'm looking for a certain sound, but on the other it's uncontrollable. Some things you just can't reproduce. Sometimes it doesn't function well enough because it's not producing a strong enough signal or the signal disappears the moment you move your hand. That's not good, especially if you're selling the circuit as a product, as we are for this project.

AA Would you say this project is typical of your approach: trying things out, making circuits, seeing how they work?

GJP I've been doing this since I was 16. [Picks up a circuit board, switches on the radio and tunes it to the frequency of the small transmitter.] Right from the outset I was fascinated by the connection: you make something, you touch something in the circuit and that causes something to happen somewhere else. It's got scope. There are just so many aspects to it and if you just think about all the things you can do with it…. You need incredible concentration to find out exactly what you can do with it. To most people, the sounds I make seem totally uncontrollable: it's noise that you'd rather shut out. These circuits already existed of course, it's just that I discovered there are so many other fascinating elements in them.
The starting point in my work is

top –Tina Frank, Bas van Koolwijk and Gert-Jan Prins.

bottom – Justin Bennett, Tina Frank, Bas van Koolwijk, Jérôme Noetinger, Gert-Jan Prins and Billy Roisz, *The Synchronator Orchestra*, live performance at Sonic Acts, *The Dark Universe*, 2013. Originally commissioned for Kontraste Festival, *Electric Shadows*, Krems, 2012.

always at the micro level, and then I magnify that.

AA What do you use in your live set-up?

GJP I make a combination of the small transmitter and receiver. The receiver's output is fed back through the mixer to the transmitter so you get real feedback. That's the basic principle I used. One bottleneck in this kind of system is the delivery of sound to the transmitter. This is a very specific transition that you can experiment with a lot. You can, as it were, modulate the transmitter. For a long time I've been testing different ways that this sound signal influences the transmission signal. I use different ways of finding out exactly what's going on, and I've discovered that some set-ups deliver better quality and sounds than others.

AA Could you elaborate?

GJP I use the small receiver to pick up the self-generated FM signal and then I feed that back in again. I use radio technology as a complex filter for audio and bring the complexity of radio technology into the audio. There are lots of aspects to it. Each component behaves slightly differently. I've got transmitters built years ago that I still use. I've still got one with a test print in it that I got from a former neighbour. He developed it in 1994 for Philips for a car radio that could tune itself automatically to a frequency, so that when the car turned a corner and could no longer pick up a certain signal, it would still pick up the right frequency. Radio signals in between buildings sometimes move in remarkable ways. It gives me more ways of controlling what happens, and the quality of sound is really good, too. The receiver that this test print is in is a fusion of objects from various periods. One of the components is from a British modular DIY tuner from the 1970s. You used to be able to buy parts separately and connect them to each other to make a really sensitive tuner – it was important back then because everything went through antennas. That's all disappeared now. The strange thing is that this combination of components still works really well. The quality of the receiver adds to the quality of the sound. I've been using this receiver for nearly twelve years now, with just a few tiny modifications. I always want to re-use boxes I made earlier. I've had some of the boxes – I mean the boxes you put the components in – for more than 30 years, but I use them again and again in different ways. Perhaps it's a romantic idea, but I think it's also a way of carrying history in what you do. I really like that, because you've already got a relationship with the material: you've had it in your hands before and then you make something new with it. But sometimes it's just because it's a functional box: nice and light with lots of holes.

AA How does it relate to electronic sound generated by sine waves and oscillators?

GJP There are several more steps to my transmitter-receiver system: first you transpose the signal to a totally different frequency and then you bring it back. That's what radio does, of course. It's a somewhat longer signal path. I'm fascinated by the idea that when you're working with FM radio and radio technology – with VHF in any case – you'll always have underlying noise: a base layer of noise. It's not present in purely electronic sound generated by a function generator using sine waves and square waves. You can compare that base layer of noise with water. When you generate noise using one of my small transmitters, you're transmitting it on an empty carrier wave. If you remove the carrier wave you get noise. Working with feedback systems, it's possible to incorporate the noise in the signal. You get all kinds of combinations that you couldn't easily generate any other way. I kept on using FM radio for practical reasons. The noise sounds incredibly good I think. It's a physical and manageable format. Very occasionally you accidentally pick up a regular broadcast and that can add a playful element to the performance. It changes according to where you are. My live set is based on the FM wave band, usually on the quieter sections of it. When I'm playing in big cities I sometimes have to retune a bit so I don't suddenly get a blast of house music coming through.

AA Are you zooming in on the fundamentals of electronics?

GJP Electronics is all about raw materials: silicon, germanium, carbon, silver, copper. It's about electricity as a natural phenomenon. There's quite a bit of chemistry involved, too. Capacitors, resistors and transistors all contain various materials such as acids, all sorts of metals, tantalum, aluminium, gallium, arsenic. The circuits are miniature laboratories. Each of these materials makes a difference. That's fascinating to me. If it were purely about sound quality, capacitors would have to be huge blocks. That's only for audio freaks, because that kind of equipment isn't easy to carry around. I prefer making smaller devices. When performing I take a couple of extra ones with me, just in case one of them breaks down.

AA Originally, you were also a percussionist. And then you started combining your drumming and your noise-signal work.

GJP In the 1990s I did experimental recordings of percussion signals I played through my transmitter-receiver systems. I remember that if I recorded it to tape first it hugely increased the noise factor of the tape going through my system. That wasn't good. Then I passed the percussion sound through a DAT recorder to the transmitter, which made it possible to really fine tune the sound that was produced between noise and no noise. I was able to create layers with them: mixes and distortions. You could move really nicely through the layers. You'd never have managed that with a tape recorder. That's the role of the recording device. Nowadays you've got Pro-Tools. It's just as easy. You could probably do it with telephone now. But in the mid-1990s you needed a studio.

AA At a certain point you developed the Synchronator with Bas van Koolwijk. And then you also started using visuals. How did that come about?

GJP In the mid-1990s I was going full steam ahead developing transmitter-receiver circuits for my sound research, mostly at STEIM in Amsterdam. I wanted to fully explore the simple principle and chart it, research it, develop it and change things about it. The signals I transmit can also be received by an analogue television. In that period I was curious what that would look like. If the transmitter is transmitting at 100 MHz, for instance, then you'll also hear it at the harmonic frequencies 200, 300, 400 and 500 MHz. Television can easily receive 500 MHz in the UHF band. What you see is a load of stripes. It looked really good and it created a logical connection between sound and image. I already had a couple of televisions I could mess around with. I found it too restricted after a while and started wondering how I could improve televisions. I examined the various components in a television, such as the tuner, and built my own system. But the problem was that it was impossible to record the images properly because there were no video recorders that could do it. So that was a limitation I encountered between 1998 and 2000. I did make a video for the local Amsterdam station Park TV, but I recorded that one by pointing a video camera at a monitor. Bart Rutten – who now works at the Stedelijk Museum – put me in contact with Bas van Koolwijk. I'd made a video for a compilation

DVD on the label run by the Italian Domenico Sciajno, and that led to Bart Rutten booking Bas and me for the 5DaysOff music festival in 2005. After that, Impakt in Utrecht offered Bas van Koolwijk a residency so we could develop a device that would be able to record the signal. We spent two months there, soldering the whole time. Bas knew a lot about video technology: about the display and about related parameters such as the synchronisation signal. I knew more about electronics, but not that much about pure video technology. I had to improve my skills considerably while I was there. We learned a lot from each other, and we still do. While we were there we developed a circuit we called the Synchronator, and a few years later we had a commercial version made. So our work focusing on recording a signal led to a device for synchronising image and sound.

AA I understand you're busy working on a prototype for the next Synchronator module.

GJP Yes. The Synchronator Color Control is a device that you connect to the Synchronator. It's got a stereo audio input, and you can use it to set the colours and intensity of the Synchronator's output signal. It's controlled manually using knobs. It's got three RGB outputs, which means you can feed it a stereo signal and the difference between left and right also gets translated into visual output. Although the first Synchronator could output red, green and blue, you needed three audio signals to do it. You could use an audio mixer to produce three signals, but it's more problematic and it's harder to control.

AA Am I right in thinking you focus much more on analogue than digital technology.

GJP Until now it's been mostly analogue – except for the recording. I need digital equipment for that. We use an Arduino-related micro-controller with the Synchronator Color Control, partly to control the digital volume adjustments. And the internal synchronisation code for the Synchronator machine is digital. We use digital control codes, but the output is analogue.

AA Are your Synchronator performances entirely improvised, or do you plan a structure beforehand?

GJP Of course you need to know exactly what sort of sound the self-made devices make. There's quite a lot of pressure when you're up there on stage. You don't want a concert to be boring. It's got to stay fresh. I've been improvising for a long time now, and what's really important is knowing what you shouldn't do. All the performances we've done have taught me what to avoid. And reaching a point where it works in performances with other people can also be a struggle. How can you prepare for that? I do think ahead of time about roughly what should happen during a performance. Very often I start soldering again in the last few days before a show. It's not a good idea to keep on hammering away doing the few things you know work. The trick is to make sure the fascination for your own material stays fresh. Each time you play it should be like you're taking a new breath. When you turn a device on you should think, 'Wow, that's a really good sound. That's the one!'

AA Could you take me through a Synchronator show?

GJP If I'm playing with Bas then we connect our signals to each other. Bas gives me a signal, and that creates new connections. The duo performance is a ritual. You build up the tension together and that's expressed in the performance. As long as it's good, it's good, and then you can keep on going. And when it's gone, it's over. That's the way it is. There's not

Gert-Jan Prins, *Shielded*, installation,
2010–, work in progress, *Hear it!*,
Stedelijk Museum Amsterdam, 2011.

Gert-Jan Prins, *Cavity: the Capacitive version*, installation, Projectspace Onomatopee, Eindhoven, 2010.
top – the outside.
bottom – the inside.

Gert-Jan Prins, *Reduced Objects*, installation, Projectspace Onomatopee, Eindhoven, 2010.

much I can say about it. Improvising is all about experience. And it's a battle. I talked a lot about that with the Dutch drummer Han Bennink. He's a brilliant improviser and he's had loads of experience doing solo performances. The first twenty minutes are usually a big struggle. You often, but not always, have to really keep on pushing in an improvisation and then suddenly it crosses a point and starts working all by itself. When I'm playing alone or with Bas, the best is when things start happening by themselves – things just start coming out of the equipment, and you don't have to do anything. You don't even need to touch it. Something happens and it turns into a sort of self-propelling system. Maybe that's something I'm aiming for in a show: that moment when there's nothing left for me to do, when I could just walk away because it's running by itself and stays interesting. Sometimes I do actually move away when that happens. I take a step back and keep my hands off it for a while. But after a bit I start thinking, 'What would happen if I…?' And then I step back up and it's gone and you have to build up all over again.

AA Has the fact that the system becomes self-propelling got anything to do with the technology you use?

GJP If you work your way back to the circuits then it's logical that something of the kind might happen because there are unstable elements. The radio signal I use is by definition unstable. If you tune into a tipping point, or the 'side', of a signal, then you get all kinds of effects locked up in the complexity of radio technology. All kinds of drag effects are inherent to the tuning circuit because it's electromagnetic. It drags and you get the kind of viscosity that you can't fool around with. It's funny that magnetism has a sticky quality. It's tied up with Lenz's Law, which states that an electromagnetic field can work against itself. The tuning circuit has an elastic quality: the signal has a range to it. This quality is very specific to radio technology. The signal wants to keep hold of itself. Anyone who's ever turned a radio-tuning knob knows that. But the moment you get just beyond the range that the signal itself wants to hold onto, the signal drops away like a stone. As far as I know, you don't get this with digital technology – or with sine or square waves produced by a generator.

AA Is there a difference between performing as part of a duo with Bas van Koolwijk, and playing with the larger 'orchestra' of Synchronator players?

GJP There are six of us when we play as the Synchronator Orchestra, and you really rely on your improvising experience. The premiere in Krems was typical in that everyone also took on a musical function. I was originally a percussionist and so was Robin Fox, and you could tell that immediately. We went straight into nice double drum background. It gives the context for continuing to think in that mode, even though we hadn't thought of it beforehand.

AA Where did the idea for the Synchronator Orchestra come from?

GJP We produced a batch of Synchronators so that other people could experiment with them, and because it was pretty costly to develop. Robin Fox was one of the first people to buy one. I seem to recall that Bas van Koolwijk was talking to him once and they suggested the orchestra idea. Then he tipped off Martijn van Boven from Sonic Acts and that's when the ball started rolling. It was good right from the outset: after just half an hour with the six of us rehearsing I thought, 'We can stop now – it's fine the way it is'. And we're going to continue with it.

AA An aspect of your installation work is that the speakers are hidden or replaced with alternative systems.

GJP I'm not a big fan of speakers. I don't find them attractive as objects. I'm working with salt crystals at the moment. They produce amazing sound. I've got a little box containing a salt crystal – potassium sodium tartrate. What you hear is a sort of radio through a tiny little single-watt amplifier. [Switches on the device.]

AA How do you generate the soundwave?

GJP I run an electric signal through the crystal, which creates an electromechanical effect that causes the salt's crystalline lattice to deform. And you can hear it happening, which I find absolutely fascinating. I've now put it into a stripped-down electronics box. I call it a 'reduced object'. The boxes have a perfect size and shape that directly relates to radio technology. The ones for 30 to 200 Mhz are the best format. The boxes for 1000 to 2000 MHz are really tiny, and I find that less appealing. The boxes they used for shortwave measurement devices up to 30MHz were real juggernauts coming from a totally different kind of aesthetic. The reduced objects have had their electronics, and their functionality removed. Then all that's left is a beautiful object. I clamped a salt crystal into one of them, so the box itself functions as a resonator.

AA How did you arrive at the idea of the reduced objects?

GJP In about 2008 I was very much taken up with how devices look on the inside. There's one specific machine, a Rhode & Schwarz tuner from the end of the 1950s– very high quality laboratory equipment – that captured my imagination. The most interesting reduced objects usually emerge from these pieces of high-quality lab equipment. It has to do with functionality. The best equipment is in boxes with the most beautiful dimensions and proportions. The one I clamped the salt crystal into is the most linear box in existence. It was designed for the cleanest signal. You immediately see how beautiful it is. It's not that important to me that a signal's superclean: a clean signal can be very uninteresting if you connect it to audio…

AA In some sense this sort of box is the height of modernism, because it was made for the purest possible signal…

GJP They're definitely a high point in a certain period of dealing with technology. The technology was taken to its furthest extreme. It was the best possible measuring device of the period, the highest standard.

AA Do you find the salt crystal so appealing because you can get a sound out of it that can't be generated any other way?

GJP The sound of a crystal enters the space in a very different way than from a speaker. A speaker gives you the feeling the sound is coming from the heart and travels in one direction. But with a crystal, the whole object vibrates.

AA If you were going to develop this idea further would you make an installation set-up or do a concert?

GJP I'll just have to see how it develops. I'm working on several objects of this kind. I have to figure out if I can enlarge it and whether that has an added value. Maybe I'll stumble onto a completely new idea while working on it. I want to make a few of them and then see if I can start working with feedback – get the whole system to generate feedback. I'd be able to give a kind of mini concert with it – as long as it was in the right venue and the audience were really quiet.

AA: It generates a sound you could listen to for hours…

GJP Yes, it's good isn't it? It's also a big contrast with my performances. It's quiet and subtle. My shows are usually loud and subtle, but in a different way.

AA What strikes me about your concerts is that because the noise is so rich there isn't a moment when you long for melody and harmony or rhythmic sequences.

GJP I did consciously let go of that at a certain point. But when it comes to recording and editing for a CD I still come back to the question of how to shape it in a compositional way. I sometimes hear licks or melodies in the noise. I make musical choices. When I make a record I select recordings of the right tempo, with a good rhythm and an interesting distribution of energy over time.

AA Could you tell me something about the development of *Cavity*?

GJP The main way I get ideas is through leaving things out. My starting point for *Cavity* was a soundspace with no visible speakers. I'd made it for the *Deep Screen* exhibition in the Stedelijk Museum. My original idea was to make a space with hollow walls but it turned out I couldn't do it there. So instead it was a neutral room with speakers behind stretched fabric with the sound being played at mid-range. After that I carried on further along the same lines.

AA How did that lead onto your exhibition at Onomatopee in Eindhoven?

GJP At Onomatopee in 2010 I created a space with copper plates, *Cavity – the Capacitive Version*, and exhibited the *Reduced Objects*. At first I thought creating a space with copper would be far too expensive, but at the low point of the credit crisis prices of raw materials tumbled and at the end of 2008 it was within the budget to create space out of copper-printed circuit board. Then at the Stedelijk I made *Cavity – the Shielded Version*. That was in 2011. That was a kind of zero point in my work. It was a tent in which electromagnetic radiation was all but completely cancelled out. There's only noise in that space. No other signal is possible. There is no connection anymore.

AA Where does the noise come from if you've shielded the space within the tent from all forms of electromagnetic radiation?

GJP When noise is created by devices, it's always the product of several components. There's thermal noise from the device itself, and there's some electrical noise, and then of course you've got the cosmic noise, which literally falls in from outside and passes right through the Earth.

AA So if you build a tent that shields you completely from electromagnetic radiation and you place a receiver in it, do you still hear anything?

GJP You'd still hear a tiny bit of cosmic noise, and I think you'd still hear a little bit of thermal noise. The total electromagnetic noise is reduced in the tent by 80 to 90dB. I think it'd be great to put a tent in a tent. Then it would really all be gone. If you went into the first tent with a receiver, then you'd still hear bits of signal, and in the second you wouldn't hear anything. I'll have to have a good think about that.

AA A tent that shields you from signals is a zero point conceptually. There's no radiation. But what does that mean? Should I interpret it as a statement about the electronic radiation that envelops us?

GJP It's more about territory. Those in power use this kind of tent so they can't be bugged. They use their computers in this sort of tent because with sensitive equipment you can eavesdrop on a computer from a hundred metres away, even without Wifi. What I'm most interested in is how it feels to be completely disengaged – to be without any connection, without your phone. Some people in the tent in the Stedelijk even experienced physical sensations: they felt like something had fallen off them.

THE PERCEPTION OF COLOUR

Interview with Matthew Biederman

Arie Altena

Matthew Biederman's installation *Event Horizon* (2012) is a multichannel generative HD audio/video installation that metaphorically explores the phenomenon of an 'event horizon', a boundary in spacetime, such as around a black hole, from where light cannot escape and thus cannot be observed. To produce visual material the software of *Event Horizon* iterates through a basic generative system that uses pure fields of red, blue, and green, modulated, layered and interspersed with black. For the sonic component, the same code is translated to drive a set of software-based synthesisers to generate a series of overlapping drones.

Arie Altena In *Event Horizon* there is clearly a fascination for colours. Maybe we should start by talking about colours as physical waves, because in most of your works there is a connection to the idea of the electromagnetic spectrum?

Matthew Biederman I have a fascination for perception, for the idea that our eyes and brain and body decode electromagnetic waves as images. You can think about it in the same way as a radio that detunes and retunes the radio waves into physical waves that we can hear, or as a television, which does the same, converting radio frequencies to light frequencies. Also an X-ray photograph retunes chunks of the electromagnetic spectrum into wavelengths we can see. *Event Horizon* takes ideas from astronomy, physics and cosmology and sort of compares them to neurological theories concerning perception. I'm very interested in the ways we perceive the world. In astronomy and physics the event horizon is the edge of a black hole. But I think each person is also one's own event horizon, meaning that simply by being present, each of us perceives the world individually and therefore differently. I conceived the installation, including the sounds, visuals and the arrangement of the space, in such a way that no matter where you stand in the space, you have a very different understanding of that space. There might be ten people in the space, but each of them will perceive the space in a different way. This is also what fascinates me about colours. There is a famous quote by the artist Josef Albers, which runs something like: 'I could stand in front of a room of people and say: everybody imagine the colour red. I could be fairly certain that everybody is imagining red, but I can also be very certain it's a different red'. Even the act of naming a colour presents an interesting problem. When does red become orange? When does blue become green? We have been trying to classify colours for a long time. Only now, in the digital universe can you finally quantify a colour. You can put a number to it, or a set of numbers, on a digital scale, and say: that's 127 red, 8 blue or 12 green, and it will give you a certain hue, saturation and value. Within digital systems, there is now a quantified standard that didn't exist before. In the past all colour researchers – Goethe, Newton, Itten – made their own colour wheels and came up with their own models. Now we can quantify it. But still, there is information that is inherently missed when a picture is digitally sampled.

AA Your installations and projections use a lot of different digital colours and hues that are almost the same. But as far as I understand, every computer screen is different, and every beamer is different. How do you work with that? How important is it to get the fine-tuning exactly right?

MB I try to tune the works as best as I can. Certain pieces require a specific technical solution. For *Event Horizon* I look at the way the gradation goes to black. I also have a piece *R+G+B* that is specifically about the digital sampling issue. It just counts through all 65 million colours for an 8-bit screen. In that one I just watch it to make sure there is a clean step between each of them. It's a fairly simple piece, but I find it interesting to map out all the colours a computer can generate. Even if – and this goes back to the perception problem – a different beamer and a different screen and computer (and different combinations of those) do render the same piece with slight differences. But who is to say which is the correct one? I look at it, I fine-tune it, but somebody else sees it differently. That's exactly the grey area that I want to explore. There is another piece called *Ouroboros (Or Color Bars Matched Horizontally One by One)*, where the computer creates all 16.7 million colours, from these it makes a set of vertical stripes and matches them. That piece is really about the idea that only another digital system can recreate those colours and represent them exactly. You might see a certain colour as purple, while I see it as blue, and somebody else says, no it's something else. But the piece runs on a digital system that can sample it, can state what it is, and match it exactly.

AA When ten people look at *Event Horizon*, they all see something different. Is that mainly because of how our eyes work, or is it also in the spatial set-up?

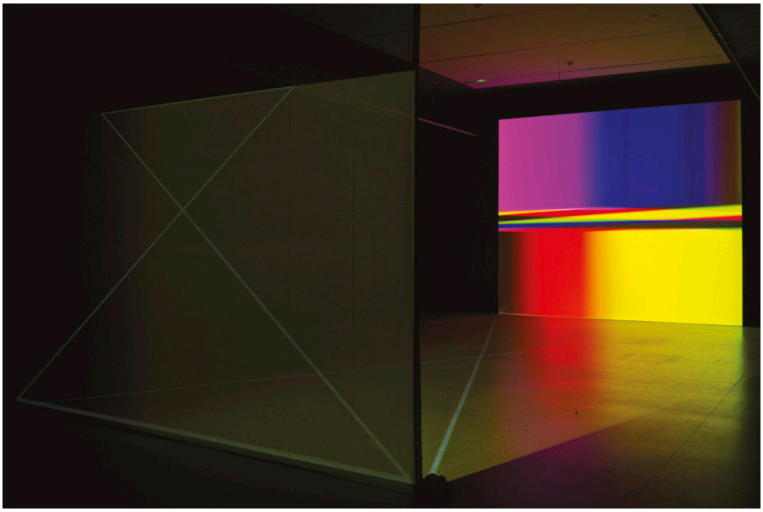
MB It's both. It has to do with the architecture of the space, so just by standing in a different spot, you perceive something different. But *Event Horizon* comes also out of the ideas that neuroscientists are proposing now as the next step after the phenomenology of Merleau-Ponty. They say that the brain doesn't live in a jar that is connected to our eyes and ears – which has been the model for a long time. Instead we sense the world with our bodies and by moving around. The philosopher and neuroscientist Alva Noë is a big proponent of the idea that our body is also a sensing organ – and not just our brain. I've been thinking about how to create a situation where this becomes apparent, and *Event Horizon* is an attempt to do this. The audio uses the architecture of the space, even when you just turn your head slightly, the audio sounds very different. I wanted to make a space that pushed people to move around to look and listen. This is also where the idea of an 'event horizon' comes in. There is the horizon of you moving around: your body as a horizon. The horizontal horizon on the screen becomes a *moiré* pattern, and it looks as if there is something three-dimensional happening. It is a a technological horizon, because the display cannot go beyond a certain point, so it creates a *moiré* pattern. A 3D-effect is created in your brain, out of something the computer can't recreate. The screen in the middle of the space is another physical horizon, and it breaks up the projection. Because it's translucent you can see on it and through it simultaneously. With it I try to evoke the idea that, a horizon is not necessarily a physical thing. It moves and things pass by and through it all the time.

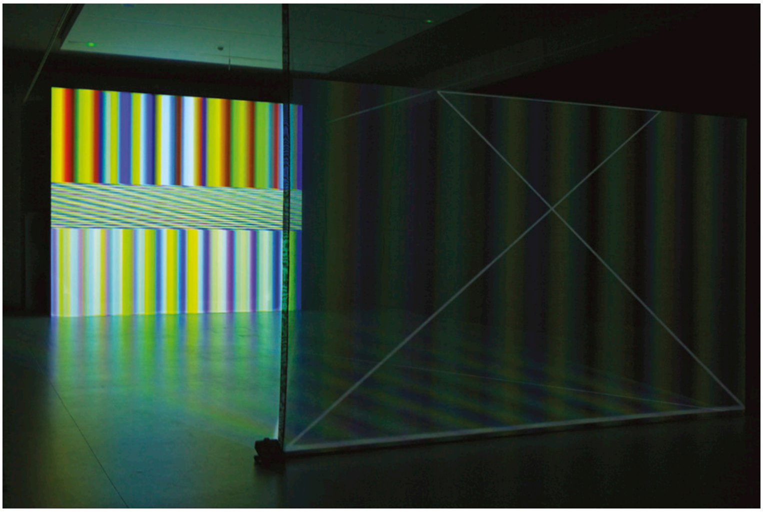
AA What happens exactly in with the generated colours and imagery? You mix colours – can you explain how that functions?

MB It's a technical trick and it's really basic: a mixing of RGB colours interspersed with black. Then I add to or multiply them in different ways, to emphasise the idea of an RGB universe. By adjusting and slightly shifting the angle and the frequency of the stripes, the *moiré* pattern that I mentioned is created in the centre of the screen. In fact the edge pixels stretch so much they resemble stripes. *Event Horizon* is generative, so there is no ending or beginning. People tend to stay in the installation, sometimes to see when it starts looping, but that never quite happens. The piece works according to a certain rhythm, and there are certain states that it goes in and out of, but it is never quite the same, nor is it ever the same arrangement of colours.

AA Because you work with these big fields of colour, one is reminded of colour field painting, Barnett Newman, the idea of sublimity and colour…

MB I have always been a big fan of minimalist colour field painting, of pure saturated colours... I think there is something very provocative and sensual about it. Being awash in colour. There is a meditative aspect to it that I also try to evoke. I consider a work like *Event Horizon* to be more connected to painting and conceptual art than to most other media art. I have intentionally stepped away from the kind of interactivity where 'if I do this, then that happens'. I see that as an easy way out. This work is about having to make a decision about the composition. I tried to push myself into a position where I have control. Of course I worked with algorithms again, so I don't have complete control. But there is more control than in interactive work. The works I'm making use a systematic approach. They're based on rule-based conceptual ideas, which are then applied to time-based media. I look at the work of Sol LeWitt, Barnett Newman, and Josef Albers, and I'm trying to be sensitive to some of the systems and colour issues that they were working with. And I wonder what you could discover if you explore these issues over time.





Matthew Biederman, *Event Horizon*,
multichannel video installation, 2012,
Kontraste Festival, *Electric Shadows*,
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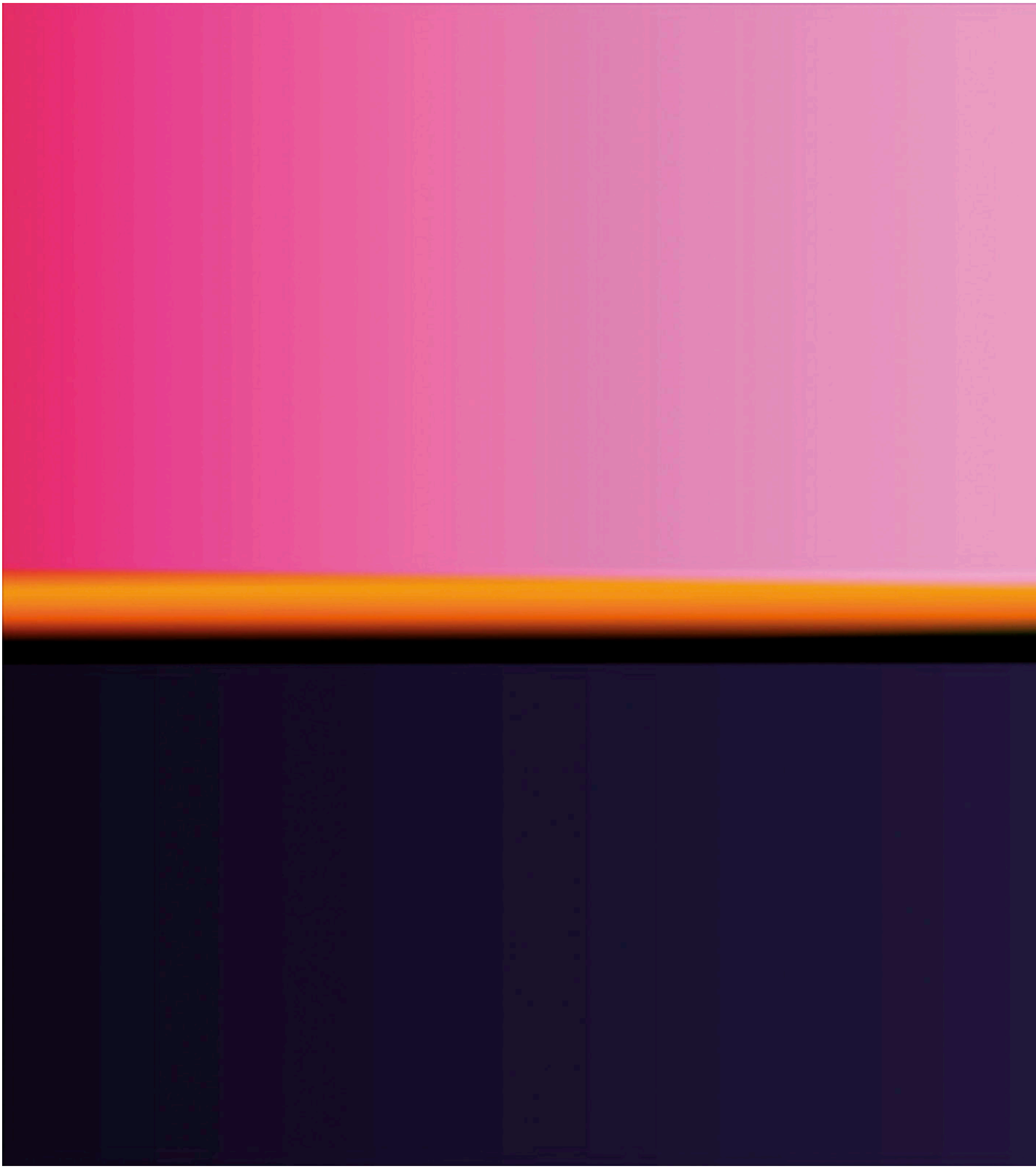
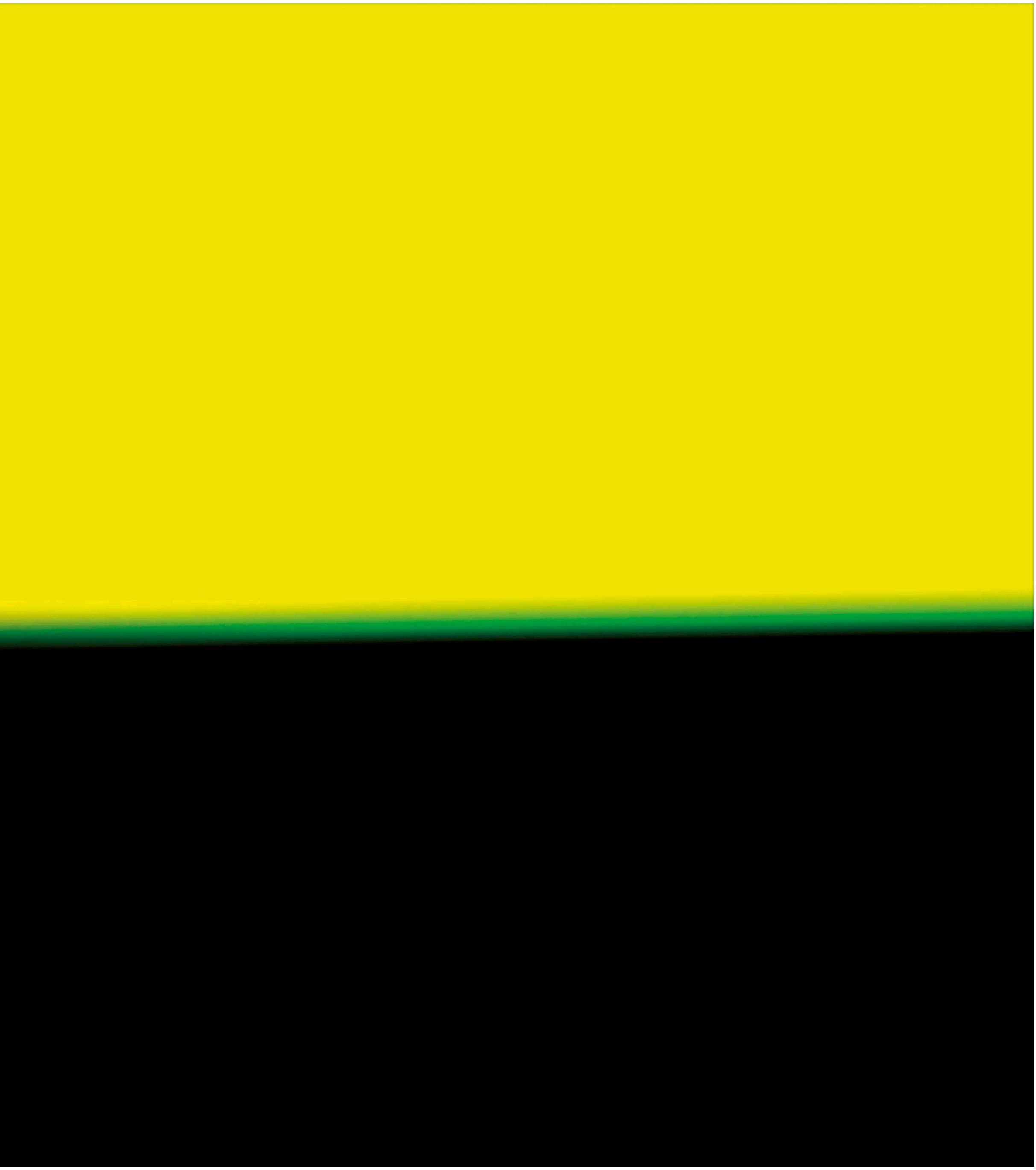
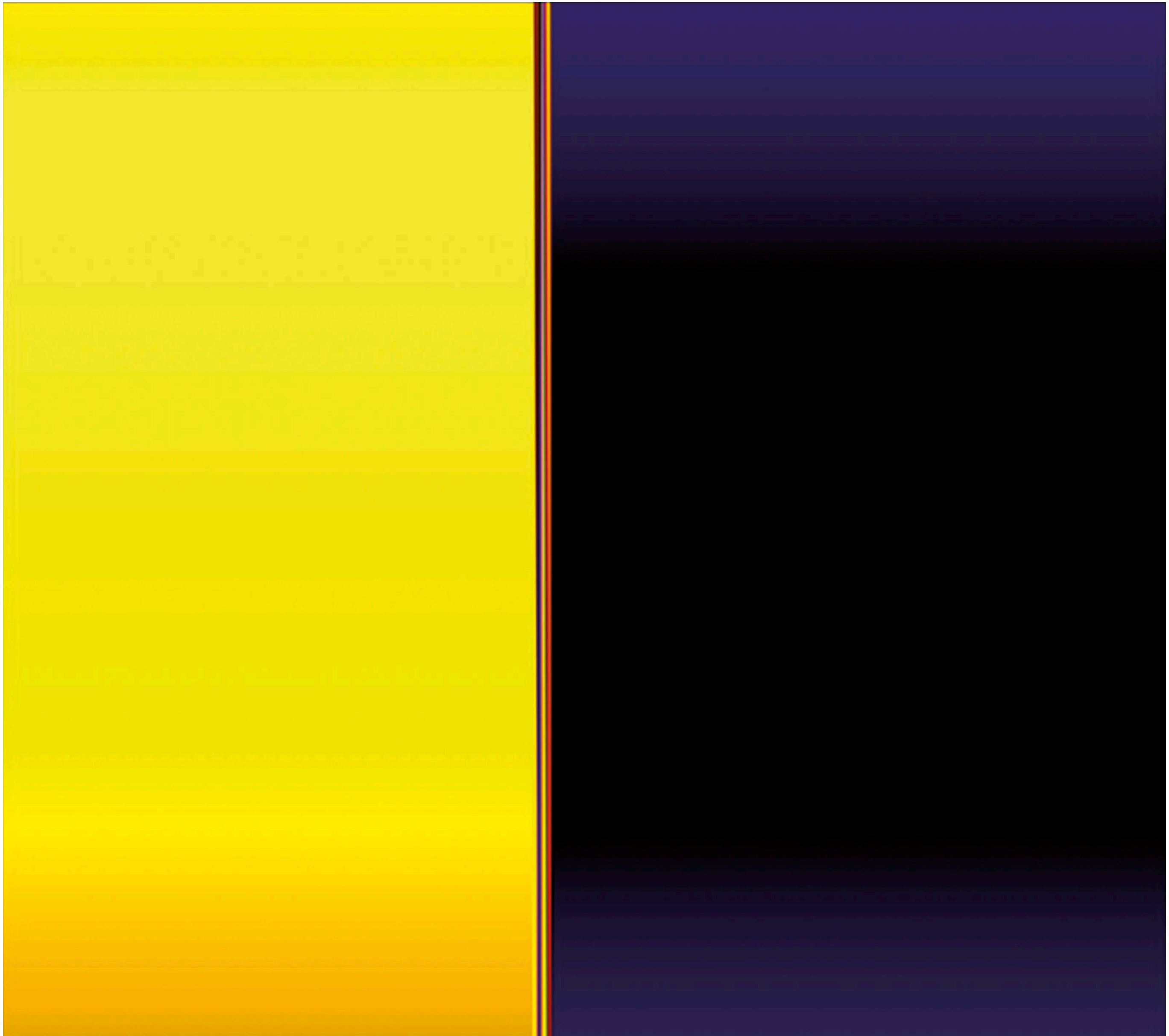
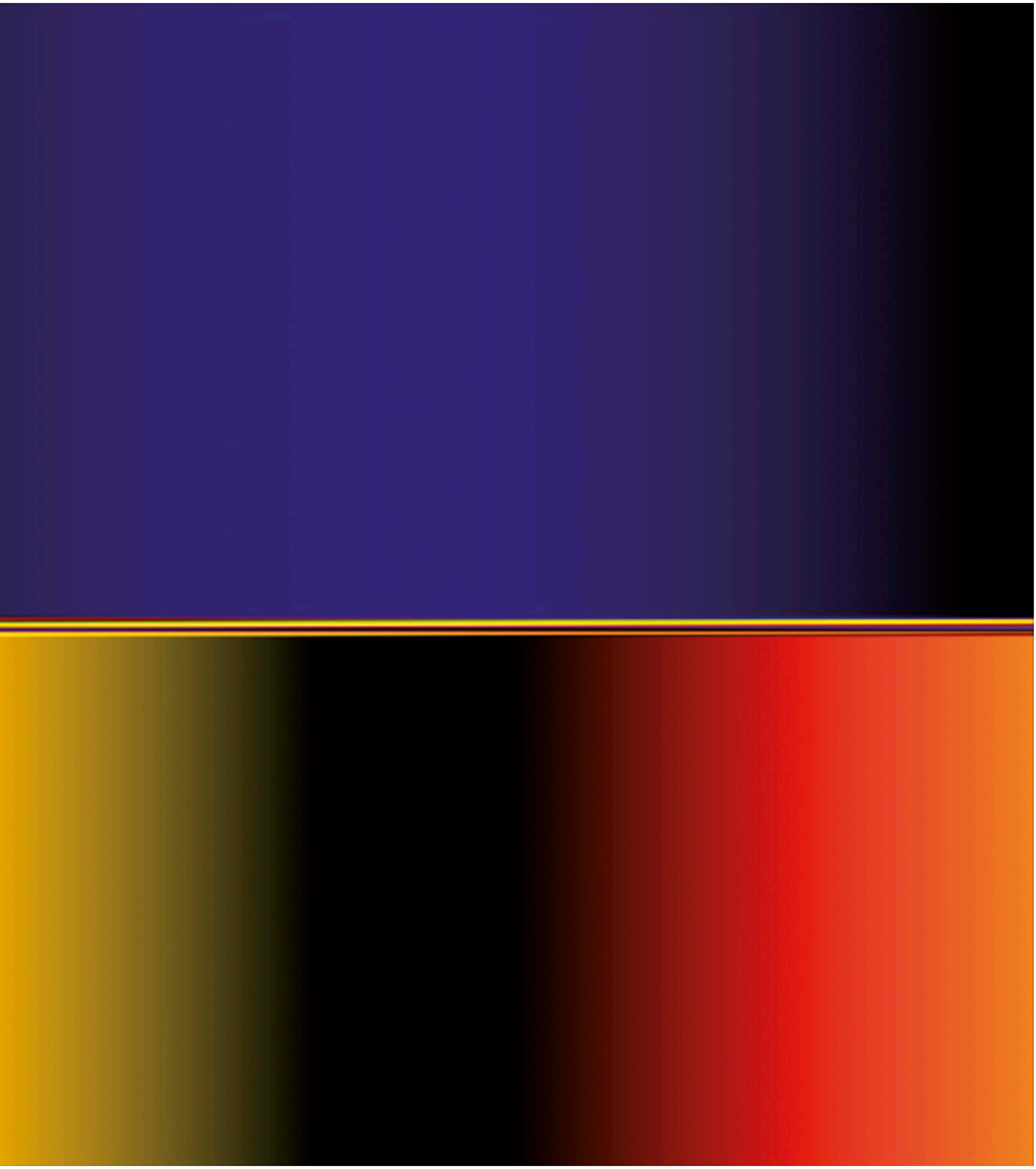
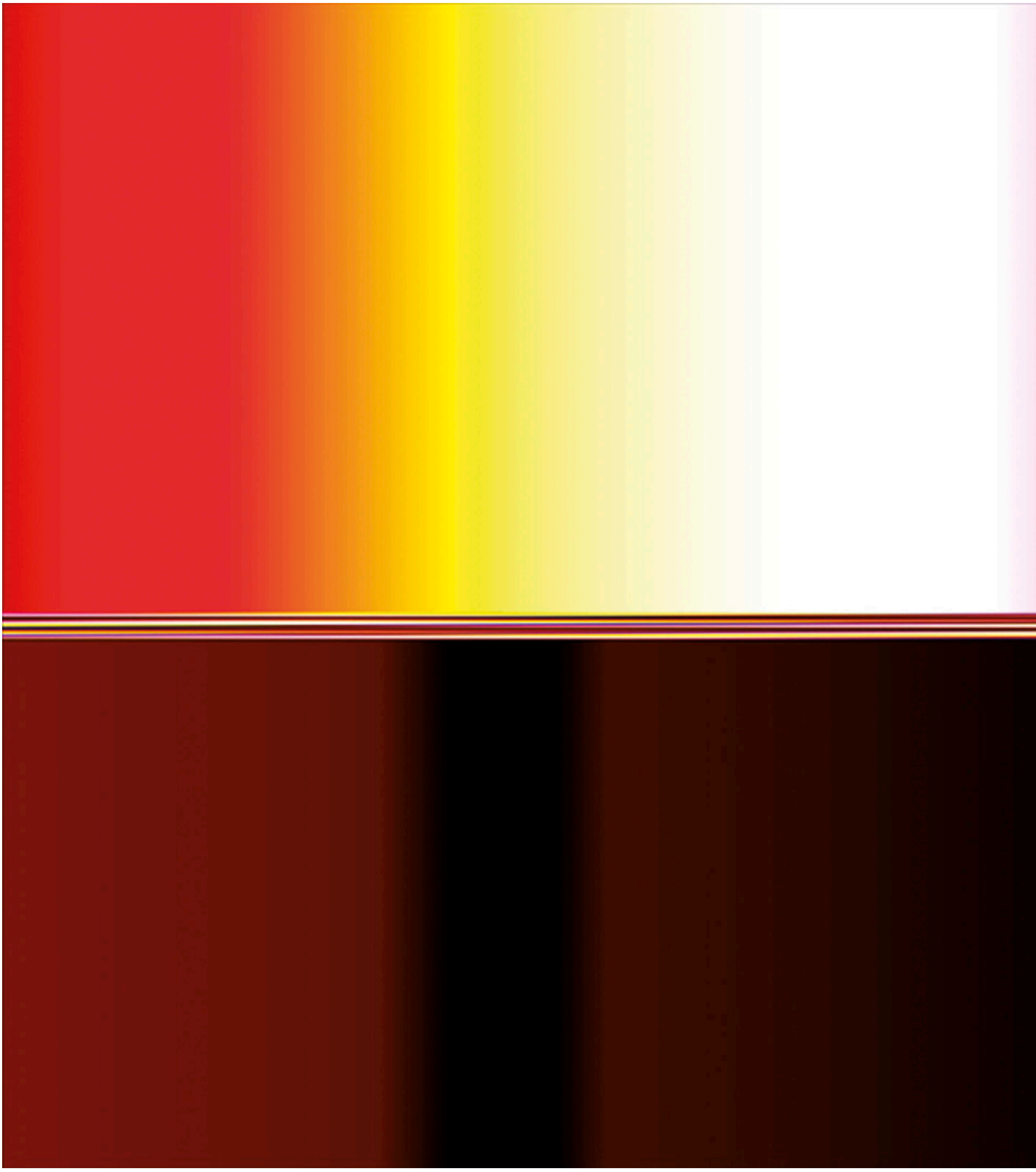


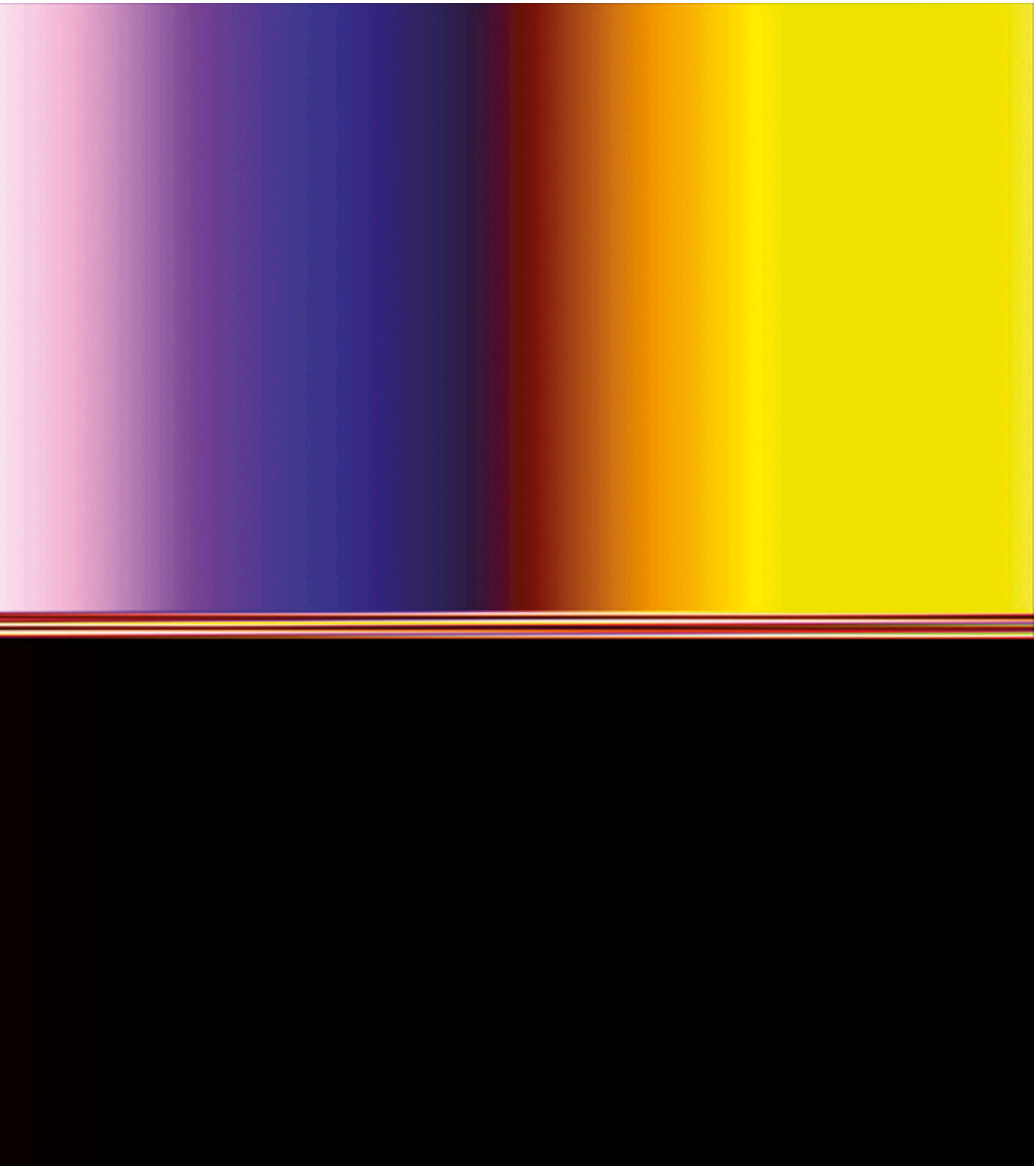
p. 186–201 Stills from Matthew Biederman, *Event Horizon*, 2012.

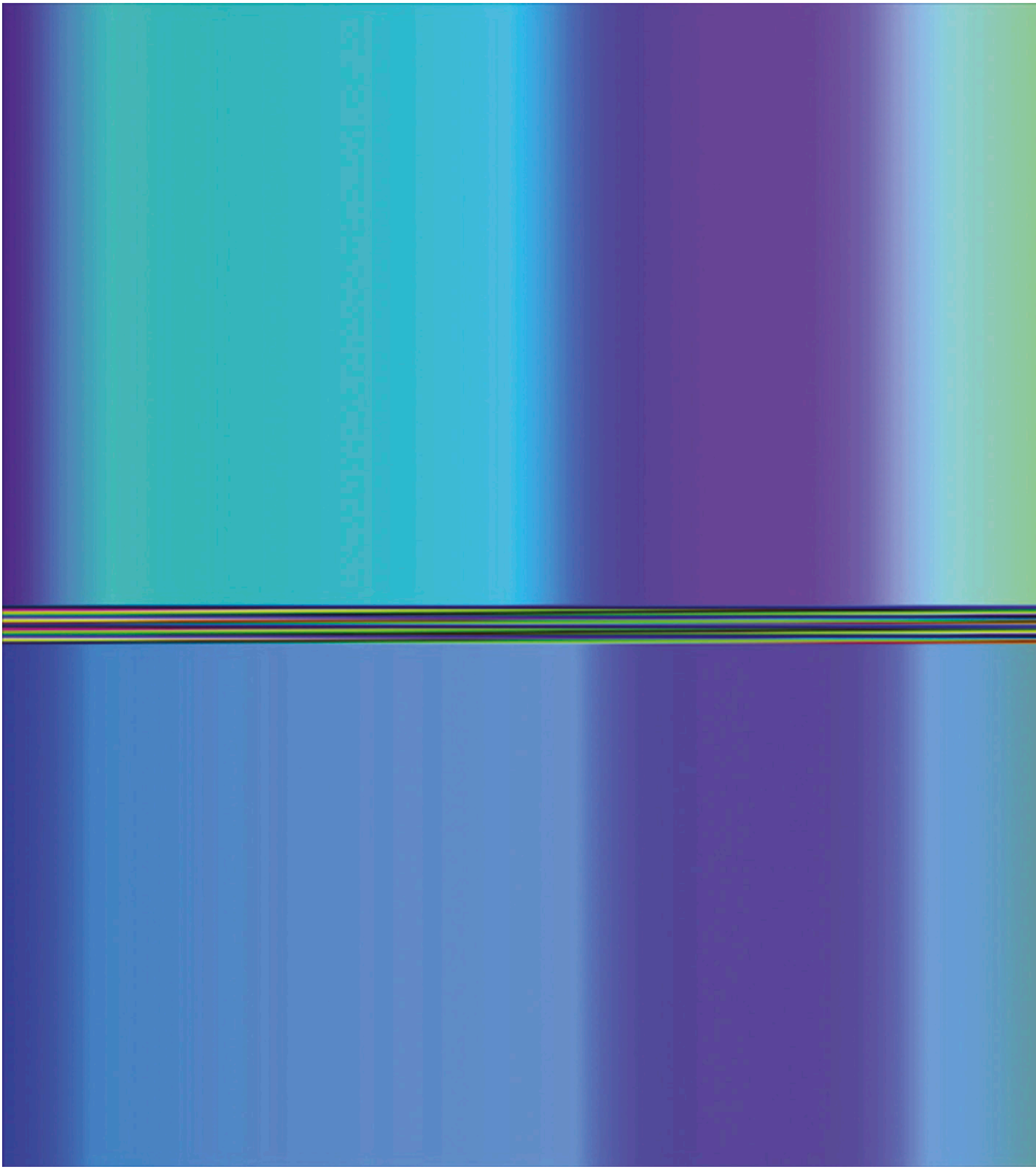


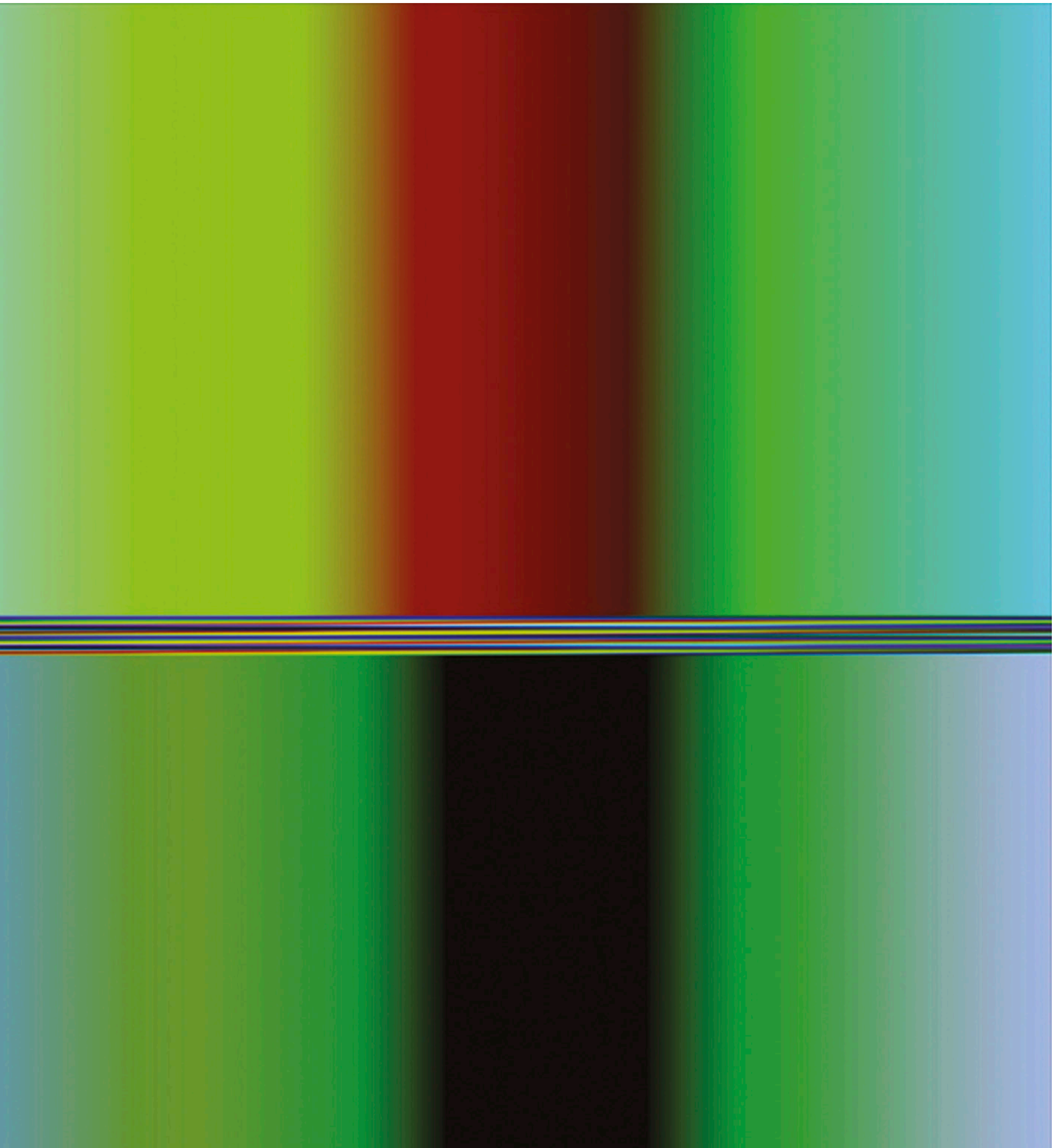


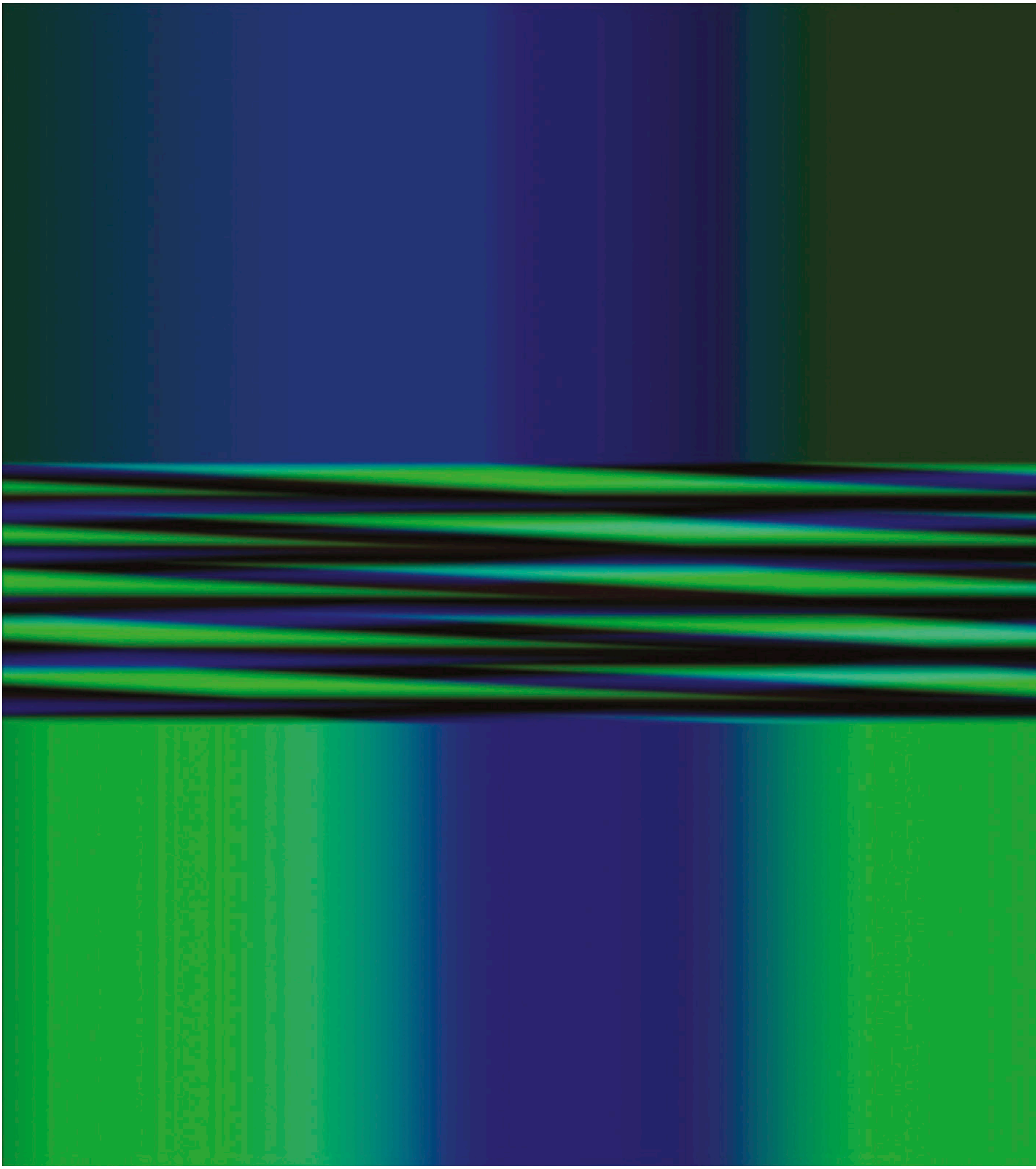


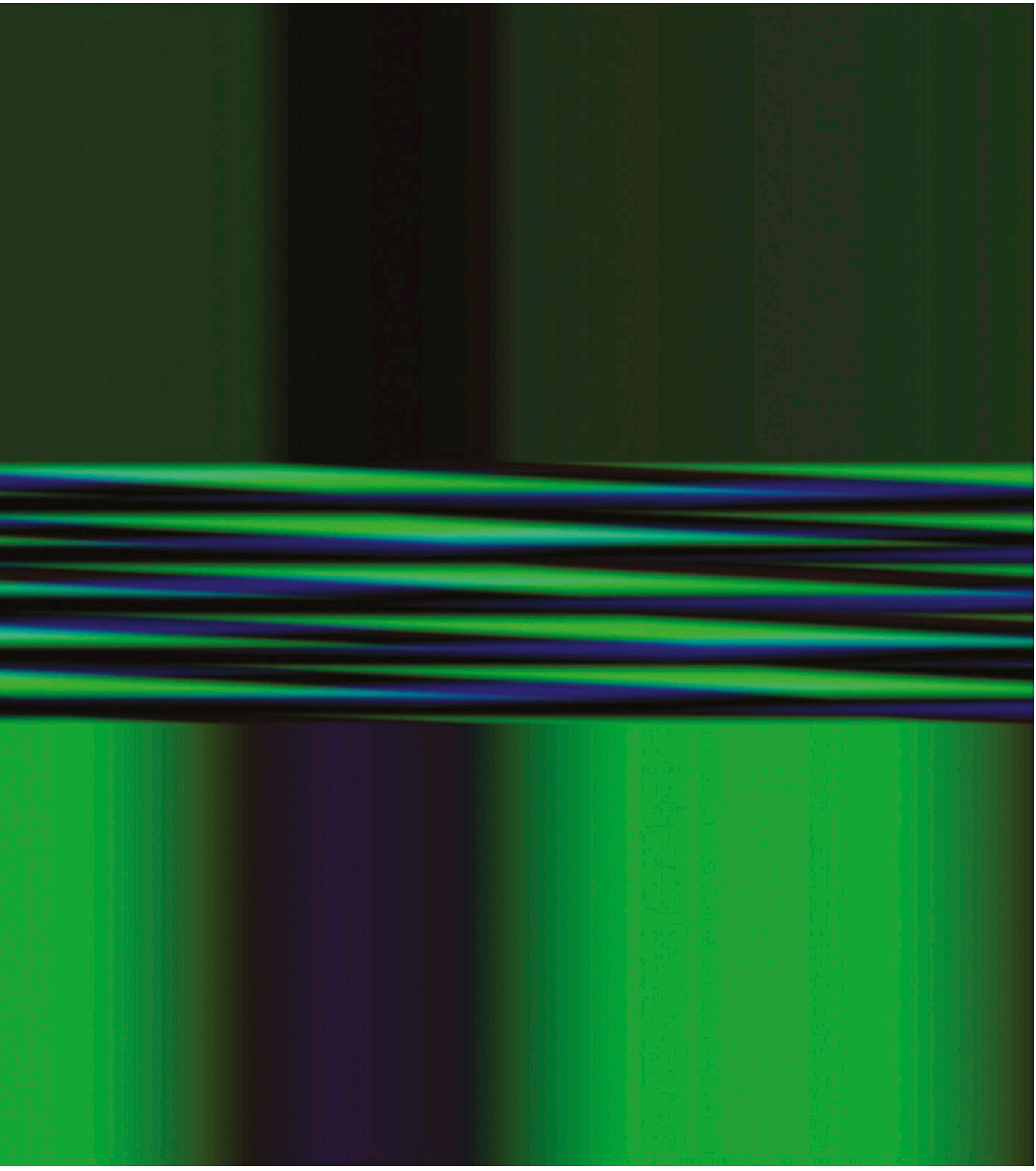












ON ~~THE~~ BLACK UNIVERSE IN THE HUMAN FOUNDATIONS ~~OF~~ COLOUR

François Laruelle

The original text ‘Du noir univers: dans les fondations humaines de la couleur’ was published in *La décision philosophique* 5 (April 1988), pp. 107–12. The translation by Miguel Abreu was first published as ‘Of Black Universe in the Human Foundations of Color’ in the catalogue *Hyun Soo Choi: Seven Large-Scale Paintings*, New York: Thread Waxing Space, 1991. In 2012 this text was the subject of the event ‘Dark Nights of the Universe’ – a four-night theoretical exploration of mysticism in dialogue with ‘Du noir univers’ – organised by Recess in conjunction with The Public School New York. This text replicates verbatim the text used for this event. Reprinted by kind permission.

In the foundations of colour, vision sees the Universe; in the foundations of the Universe, it sees man; in the foundations of man, it sees vision.

The Earth, the World, the Universe have to do with man: the Earth a little, the World a lot, the Universe passionately. The Universe is the inner passion for the Remote.

Man works the Earth, lives in the World, thinks according to the Universe.

The Earth is man's ground, the World his neighbour, the Universe his secret.

The Earth is the strait through which passes the light of the World; it is the tongue made of sand and water upon which, standing, man strides against the World.

The World is everything too vast and too narrow for the Earth, and again too narrow for the Universe.

Man gropes around the World and the World floats in the Universe unable to touch its borders.

Into the World of narrow-minded thoughts, man brings the emotion of the Universe.

The Universe, an object greater than the World, is not the object of thought, but rather its how or its according to.

The Universe is an opaque and solitary thought, which has already leapt through man's shut eyes as the space of a dream without dreaming.

The Universe is not reflected in another universe, and yet the Remote is accessible to us at each of its points.

The World is the endless confusion of man and Universe, the Universe treated as man's object.

The forgetting of the essence of the Universe is less noticeable than the forgetting of the World.

The forgetting of man as One(–of–)the–Universe and the Universe as One–through–man is less noticeable than the forgetting of being–in–the–World.

II

In the beginning there is Black – man and Universe, rather than philosopher and World.

Surrounding the philosopher everything becomes World and light. Surrounding man everything becomes Universe and opacity.

Man, who carries away the Universe with him, is condemned, without knowing why, to the World and to the Earth, and neither the World nor the Earth can tell him why. He is answered only by the Universe, being black and mute.

Black is not in the object or the World, it is what man sees in man, and the way in which man sees man.

Black is not merely what man sees in man, it is the only 'colour' inseparable from the hyper-intelligible expanse of the Universe.

Solitude of the man–without–horizon who sees Black in Black.

The Universe is deaf and blind, we can only love it and assist it. Man is the being who assists the Universe.

Only with eyes closed can we unfold the future, and with eyes opened can we conceive to enter it. Light strikes the Earth with repeated blows, divides the World infinitely, solicits in vain the invisible Universe.

The Universe was 'in' the World and the World did not see it.

Black prior to light is the substance of the Universe, what escaped from the World before the World was born into the World.

Black is the without–Ground which fixes light in the remote where man observes it. Here lies the crazy and catatonic light of the World.

Man approaches the World only by way of transcendental darkness, into which he never entered and from which he will never leave.

A phenomenal blackness entirely fills the essence of man. Because of it, the most ancient stars of the paleo–cosmos together with the most venerable stones of the archeo–earth, appear to man as being outside the World, and the World itself appears as outside–World.

III

The *black universe* is the opacity of the real or the 'colour' that renders it invisible.

No light has ever seen the black universe.

Black is anterior to the absence of light, whether this absence be the shadows that extinguish it, whether it be it nothingness or its positive opposite. The black universe is not a negative light.

Black is the Radical of colour, what never was a colour nor the attribute of a colour, the emotion seizing man when affected by a colour.

As opposed to the black objectified in the spectrum, Black is already manifested, before any process of manifestation. This is vision–in–Black.

Black is entirely interior to itself and to man.

Black is without opposite: even light, which tries to turn it into its opposite, fails in the face of the rigour of its secret. Only the secret sees into the secret, like Black in Black.

The essence of colour is not coloured: it's the black universe.

Metaphysical white is a simple discolouration, the prismatic or indifferent unity of colours.

Phenomenal blackness is indifferent to colour because it represents their ultimate degree of reality, that which prevents their final dissolution into the mixtures of light.

Philosophy and sometimes painting treat black and white as contraries, colours as opposites; they mix them, under the authority of light as the supreme mix.

The human science of colour is founded on the blackness known as the 'universe'. They cognitively unify man, the Universe, and colour theory – and their potencies in Black, which is their common reality, but in the last instance only.

A human science of colour makes the black universe the requisite that is real or immanent to their physics. Black is the posture itself of science and of its 'relation' to colour.

IV

Science is a way of thinking in black and white which studies the light of the Cosmos and the colour of the World: black, by way of its posture or its inherence to the real; white, by way of its representation of the real. A way of thinking where white is no longer the opposite of black, but rather its positively discoloured reflection.

Science is the mode of thought in which black determines in the last instance white.

The black universe transforms colours without mixing them. It simplifies colour in order to bring out the whiteness of understanding in its essence of *non-pictorial reflection*.

Our uchromia: to learn to think from the point of view of Black as what determines colour in the last instance rather than what limits it.

Philosophical technology has been withdrawn mimetically from the World, in order to reflect and reproduce it. Such technology is inadequate for thinking the Universe.

We are still postulating that reality is given to us through the paradigm of the World. We perpetuate the inhuman amphibology that confuses the World and the Universe. We believe that reality is horizon and light, aperture and flash, whereas it resembles more the posture of an opaque non-relation (to) light. When exploring the uni-versal dimension of the cosmic, we remain prisoners of cosmo-logical difference. Our philosophers are children who are afraid of the Dark.

Philosophy is thinking by way of a generalised ‘black box’; it is the effort to fit black into light and to push it back to the rear of the caverns; yet, the cosmo-logical generalisation of black does not save it from its status as attribute, quite the contrary. Black alone is subject and may render manifest the philosophical interlocking of concepts.

Do not think technology first: rocket and the lift off of the rocket. Look instead, like in the depths of a closed eye, into the opacity of knowledge where, forming one with it, the rocket passes through infinite distances. Think according to the knowledge that steers the rocket as if in a dream, heavier and more transparent than the boundless night it penetrates with a silent thunderclap. Think science first.

Stop sending your ships through the narrow cosmo-logical corridor. Stop making them climb the extreme walls of the world. *Let* them jump over the cosmic barrier and enter into the hyperspace of the Universe. Cease having them compete with light, for your rockets too can realise the more-than-psychic, postural mutation, and shift from light to black universe which is no longer a colour; from cosmic colour to postural and subjective black. Let your rockets become subject of the Universe and be present at every point of the Remote.

Simplify colour! See black, think white!

See black rather than believe ‘unconscious’. And think white rather than believe ‘conscious’.

See black! Not that all your suns have fallen – they have since reappeared, only slightly dimmer – but Black is the ‘colour’ that falls eternally from the Universe onto your Earth.

TIME, SPACE, CHANGE, SPEED, MOTION

Interview with HC Gilje
Nicky Assmann

Works by the Norwegian artist HC Gilje have been featured several times at Sonic Acts festivals. In 2013 he realised a new light installation *revolver* for the exhibition *The Dark Universe*, and performed a dazzling 'light show' using an arc of LED screens, to accompany Maja Ratkje's improvised music. After meeting with HC Gilje and discussing his work, Nicky Assmann conducted an interview through e-mail, which especially touches on his work with light.

Nicky Assmann You created the installation *revolver* for *The Dark Universe* exhibition. Can you explain what happens in this piece?

HC Gilje You walk into a space of about five by five metres in which light animations move around the inside of three metal circles. The circles are suspended from the ceiling. White, red and blue lights travel endlessly around the circles projecting light and casting overlapping shadows to create a changing band of colours on the surrounding walls. There is also a sound texture in the space, though it's hard to hear where the sound is coming from.

NA *revolver* evolved from your work *7 cirkler*. How does it differ from it?

HC *revolver* is a direct offspring of *7 cirkler*, which I made for the large sound art exhibition at the ZKM in Karlsruhe in 2012. Obviously they have several things in common. They both use light animations and circles suspended from the ceiling. Both of them use white, red and blue, and they both exploit the effect of complementary colours that appear in the shadows. They are put together quite differently though. *7 cirkler* is a composition and is closely connected to the music of the Danish composer Else Marie Pade. The light moves upwards in the circles, alternating in white and blue, and descends alternating in white and red.

revolver consists of three circles that are spaced as tightly together as possible to achieve a very narrow band of colours on the walls. The circles are hung at eye-height with the idea that people will first discover what is happening on the walls rather than look at the lights. The walls are much more integral to the work in *revolver*, as the shape is designed to work with the projections from the circles. The most important difference between *7 cirkler* and *revolver* is the structure and relation of light and sound. *7 cirkler* was a composed piece, using an existing electronic composition by Else Marie Pade. I think of *revolver* more as an audiovisual-spatial drone, an endless loop machine. It layers simple loops, resulting in a complex structure. The light in each circle has a certain width (depending on number of LEDs that are turned on), speed, and colour. Each circle has a different diameter. The light repeats the same circular movement over and over again. But since each loop has a different length (and are created so that they seldom overlap at the same point), different variations of the three combined loops will appear as brightly coloured bands on the walls. Similarly the sound consists of two loops of different lengths being played back on two different transducers in the ceiling. One high and one low-pitched sound with varying intensity are combined into a sound texture. The combined movement of light and sound creates a space that revolves around you. The repetitive slow movements somehow resonate with the human body.

NA A lot of your post-2005 installations use video projections. Why did you choose to work with this medium?

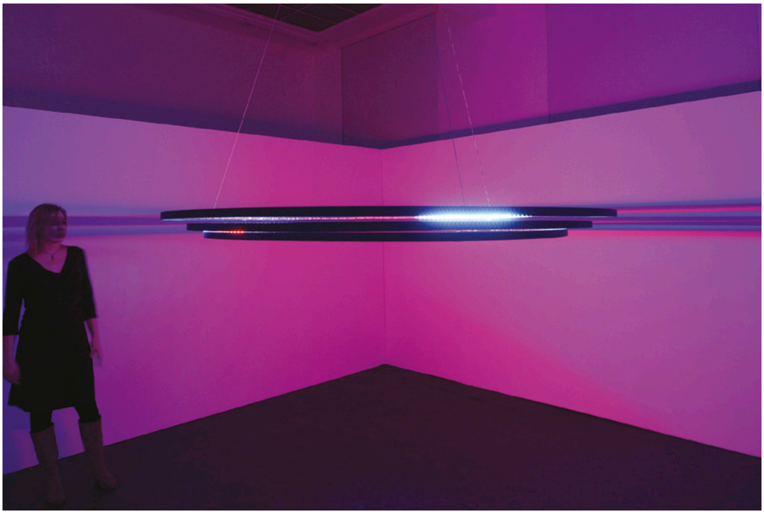
HC I think it is important to conceive of the projector as not merely an apparatus for showing images, but as an advanced light source. Using it with a computer you can combine an infinite variety of masks with millions of colours to give you a tool for painting with light. This was partly my motivation for creating *VPT (VideoProjectionTool)* back in 2007: to make the exploration of the video projector as a light painting tool easier.

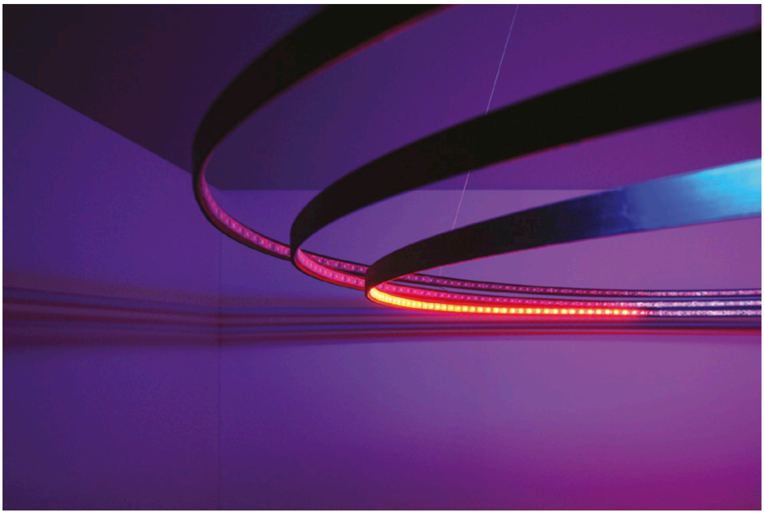
NA In your latest works you focus on working with LEDs. What is so enticing or interesting about LEDs? And why not work with a light source like a Xenon or Halogen lamp?

HC My work with LEDs began with my interest in animating shadows, using many light sources positioned around an object or person. Standard light equipment is prohibitively expensive if you want to work with a lot of lamps, so I decided to make my own dimmer and lamps based on power-LEDs. The motivation was similar to developing *VPT*, to have a toolkit for experimenting with light and shadows. Now I mainly work with LED strips because they are easy to use and relatively cheap. Coming from a light design background I often feel that LEDs are a compromise when it comes to colour and lenses in particular, but I would rather work with this affordable set-up than have to apply for large project grants to realise work.

The short answer to why I work with projections and LEDs as light sources is that they give me control over intensity, colour and focus, making it easy to work with the temporal and the spatial aspects of light. My primary interest is in creating movement in and through spaces and objects by controlling the light. For me an important distinction when working with light is whether the focus is on the actual light source or on what happens when light intersects with physical structures. I'm fascinated by the dual relationship between light and matter: a shadow or reflection indicates something about the light and about the physical characteristics of a space or object. Light reveals our physical surroundings. At the same time physical structures

HC Gilje, *revolver*, light-sound installation, 2013, *The Dark Universe* exhibition, NASA – New Art Space Amsterdam, Sonic Acts, 2013.





modulate and mediate light – without them light would be invisible.

NA Looking at the LED screen performance *Voice* with Maja Ratkje, I wondered if resolution is an important factor?

HC In one way the *Voice* performance is the opposite of what I just described, because the audience looks at an arc of very bright LED grids. These are modules normally used for huge outdoor video walls; indoors they create a lot of light. I look at them as a dynamic light landscape, creating movement through the whole concert venue, not just on the screens. This makes a huge difference – using normal monitors would have a very different result. Projecting patterns onto an arc would also be a very different experience. The resolution of each LED module is very low, about 50x50 pixels per module. My performance software for *Voice* is based on this low resolution: I use a single noise generator with the same resolution as one module as the departure point of the performance.

NA How did your work evolve through time?

HC I've been working on four parallel trajectories since I left art school at the end of the 1990s: installation, live cinema, experimental one-channel video, and stage-design. Probably not the best career decision, and it's incredible how little overlap there has been between the different fields. But I guess I've been moderately successful within these different disciplines. Right now installation is what I spend the most time on. I haven't done any videos since 2005 but I'm sure that will change. Also I would love to get more time to work with sound.

The common denominator for all my work is the relation or tension between improvisation and structure. Up to 2005 most of my work was camera based. I thought of the camera as an extension to my perception of the surroundings. Maybe improvisation is not the right word to use to describe filming with a camera, but my intention was to film whatever I found interesting without having a specific plan, and structure the material afterwards. I took my video camera everywhere, resulting in a quite large archive of DV tapes. For instance, for my *hkmark1* (1998) video I spent five days in Hong Kong, first finding the camera I wanted to use and then walking around the rest of the time filming. I spent almost half a year editing the material until it found its form. I also used live cameras extensively for my stage work with dancers, extending the movement of the dancers into the set design. For my live cinema work I have created performance systems that are flexible but at the same time have clear limitations in terms of available choices, allowing me to use the systems as extensions of my responses to the music or video without thinking – just acting. In more recent years I have turned my attention to improvising with projectors and light in relation to object and spaces, so the structural elements are now primarily physical structures.

NA You've always worked with musicians, from your work as 242.pilots to your work *Voice* with Maja Ratkje, can you say something about how you work with sound? And also how you use sound in your installations?

HC The key for me is improvisation. I've done a lot of live improvising, mainly with people from the noise scene, great people like Maja Ratkje, Jazzkammer and Justin Bennett, to mention a few. I like music when it becomes a physical experience, when it surrounds me and I get sucked into it, and then it's just a matter of responding to it. I've never actually worked with any type of direct connection between sound and image – it's my body that is the link between listening and responding. The artists

I just mentioned work with similar structures of layering, duration, repetition, and pulse that are key elements in my own work. I think sound has a quality which visual media lack, and that is to create a presence, to ground your experience in the present. When I use sound in my installations it's very minimal and not very loud. I think the best way to make sure people pay attention is to work with small changes and low volume. Usually I work with layers of loops of different lengths to create a continually changing texture. Instead of mixing the sounds beforehand I like to play each loop individually with simple transducers, so the sounds blend into the acoustic space of the installation.

NA Do you consider yourself an instrument/tool builder as well as an artist? What is the difference in how you use your instruments when composing for a performance or for an installation?

HC I am primarily an artist, but I consider instrument/tool building to be part of my practice. When I was heavily into the live cinema scene I spoke and wrote a lot about software as an instrument. Improvisation has been a mantra for me throughout my career. Improvise with a camera when recording at different locations (structure comes afterwards). Improvise with live cameras in dance performance or with recorded loops in a live cinema performance (the structure is in the performance patch). As I said, it's always about the tension between improvisation and structure. For instance, my collaboration with Maja Ratkje is pure improvisation, we never rehearse, we don't discuss the performance, we just do it. For this to work I need to have a very tight structure in my performance set-up, limiting my choices to a minimum. The Norwegian artist Kjell Bjørgeengen has written about the subjectification of the tool. He writes that it's not enough to be the creator of content, that you should either modify existing tools or create your own tools. The subjectification of the tool opens up possibilities you couldn't have thought of in advance, thus introducing an element of surprise or risk. Live performance is one thing, installation another. But I approach both with the same attitude: production of content through improvisation. The structure in my installations has changed though. For a long time I only made installations with some sort of structure that the computer navigated by making pseudo-random choices. It was essential then that the installation was real-time. I'm not so convinced about that anymore, partly because of Bjørgeengen's influence. He makes a clear distinction between such real-time generative systems, and generating content using software algorithms in the studio – and that's where the generative process stops. It's the aesthetic choices that are essential, they decide what is actually included in the final installation. For the last five or six years my process has been similar, except that I move my studio to the location where the installation will be, generate material through improvising in the space, and then make choices about composition and structure.

NA Do you have your own theory about light and the use of colours?

HC I don't really operate with a colour theory, except that I am primarily interested in what happens when the ephemeral medium of light meets a physical structure. I usually work with juxtaposing black and white (light/dark), warm and cold colours, and create movements between these extremes. A physical structure acts as a colour mixer by reflecting, absorbing, and casting shadows. A shadow tells you something about the light source, the object casting the shadow, and the ground the shadows fall onto. A shadow that moves indicates a temporal change. Shadow implies darkness, and darkness is the companion of light. As Goethe said, colour appears in the dynamic interplay between light and darkness. In general I am interested in the doubling that occurs with shadows, the reflection and mirroring.

When I create an installation I don't begin with the aim of realising a clear pre-existent idea. The installation comes out of trial and error in the studio or exhibition space. I rely on my ability to respond to the situation, be it a live performance, an empty space, a piece of music, or an object. It might be a banal answer, but I ended up with red, blue and white in both *7 cirkler* and *revolver* because it felt right. It's a process of tuning to the space I'm working in, and of tuning the installation to my frame of mind.

NA Your blog on hcgilje.wordpress.com has the subtitle 'conversation with spaces'. To me this suggests that there is a theory about space connected to your work, a theory that you discuss in your writings on the blog.

HC I started the blog as part of my three-year research fellowship at the Academy of Fine Arts in Bergen, and that was the title of my project. I wouldn't call it a theory but more a methodology. It's about 'investigating the relation between time, space and motion by developing and implementing a set of audiovisual tools to transform, expand, amplify, connect, compose and capture spaces', as I formulated it in my paper 'Conversations with Spaces' (2009). So the term is a way of describing how I could engage with spaces using my set of tools, a way of improvising with spaces, or a description of the mutual relationship between the location and myself. I project light and sound into the space, the space 'responds' by modulating it according to it own physical qualities, which makes me respond, et cetera.

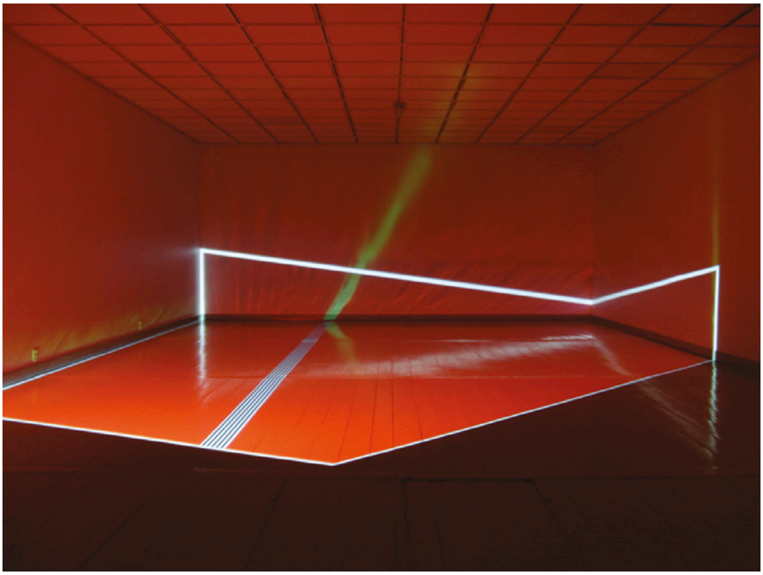
NA: Can you elaborate on the role of perception in your work?

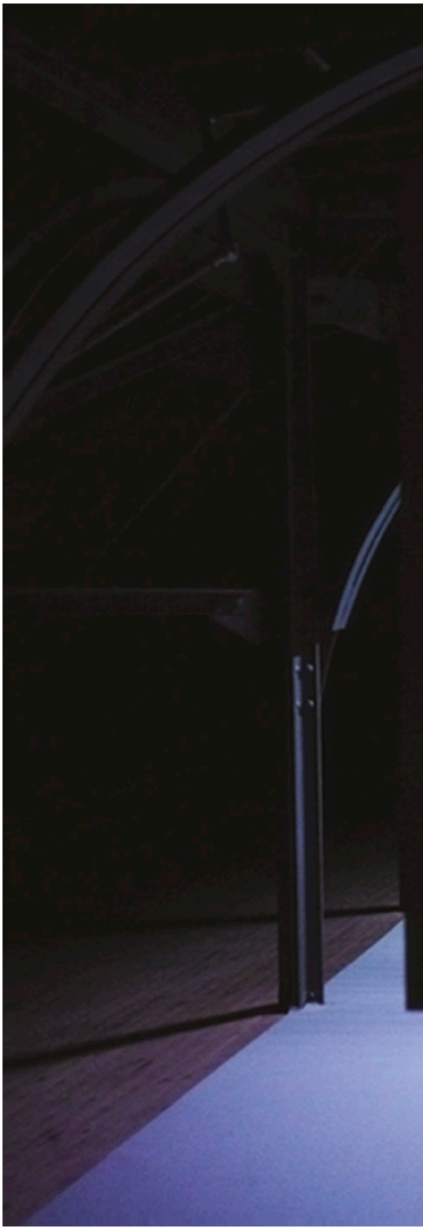
HC 'Conversations with spaces' is a way to describe this. The basic premise of my work is the concept of the embodied mind. We live our lives through our bodies, so our body grounds us in this world; the body is the link between the mind and the physical world. Perception can be seen as an active negotiation between what our senses tell us about what's out there and what we project into the world. There is therefore little difference between perception and action. Basically our body is the measuring rod and filter for all our experiences as well as the actuator, and I use that as a departure point for my work.

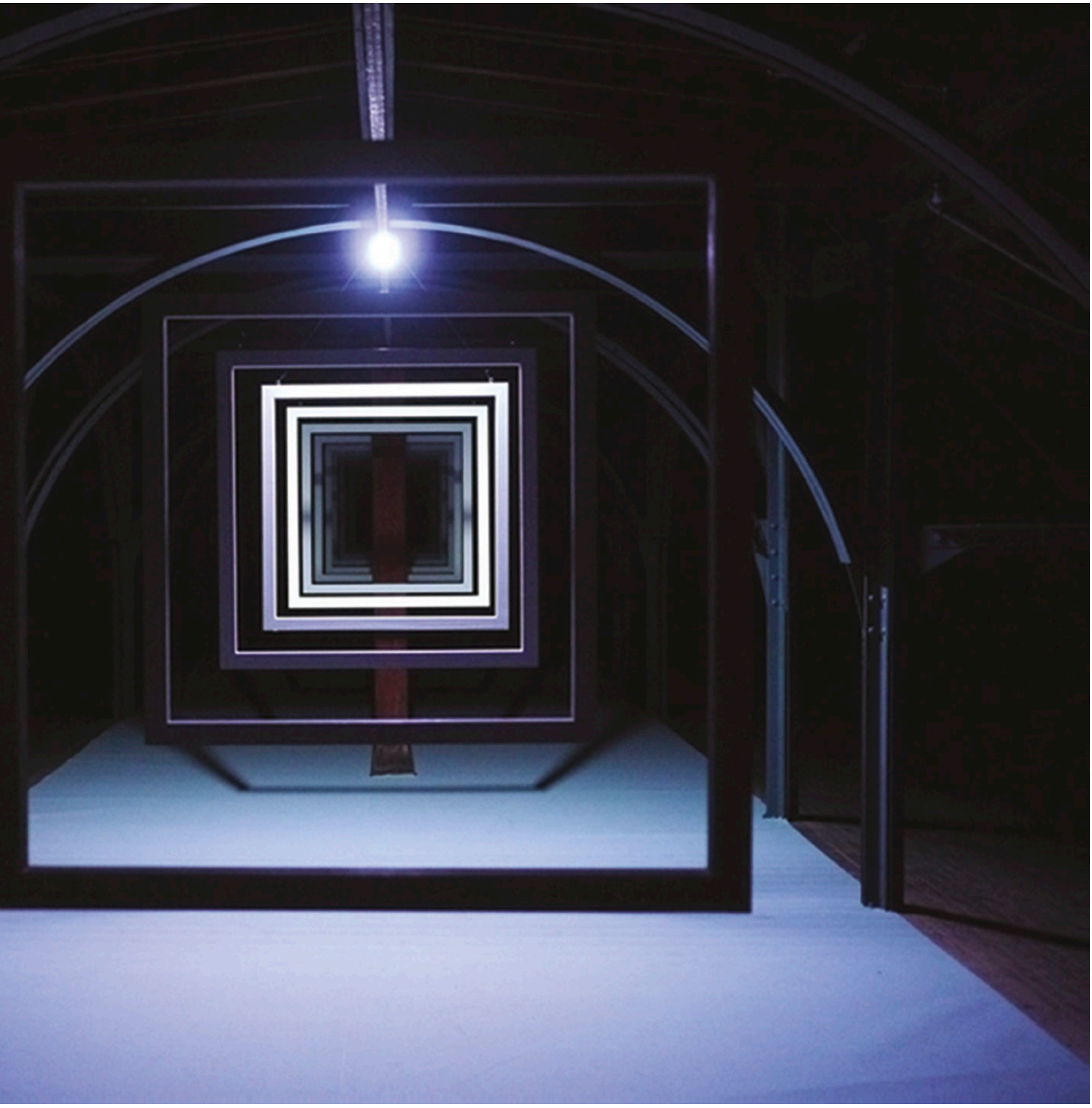
The literary theorist Hans Ullrich Gumbrecht writes about the tension between what he sometimes calls 'meaning culture' (which is about interpreting and constructing the world from the outside) and 'presence culture' (which takes the body as being part of the world). He claims that aesthetic experiences are moments of intensity – an intensification of the present. So instead of trying to make objects for understanding and interpretation, I am interested in creating these moments of intensity that I believe can act as some sort of connection between our inner mental space and outer physical environment. In an earlier text, 'Within the space of an instant' (2005), I discussed a similar idea that I called the 'extended now', referring to the presence of your body in the present, which again is probably related to Francisco Varela's description of the now as a pocket of space inside time.

I think all my installations are investigations into the somewhat blurry relations between the perception of time, space and motion (or speed). If there is no indication of time passing (which is through change or movement), how can we experience it? I think Henri Bergson's concept of duration is very interesting, the idea that everything has its own duration, be it a living organism or dead matter. We experience time at different resolutions, HC Gilje, *blink*, projection installation, 2009, Hordaland Art Centre, Bergen, 2009.

HC Gilje, *in transit*, light installation, 2012, Almost Cinema, Gent, 2012.







top - HC Gilje, *circle*, projected light object, 2011, sensxperiment, Lucena, 2011.

bottom - HC Gilje, *light space modulators*, site specific installation, IMAL Brussels,

so, for instance, something that appears static to us, just seems static because we can only experience it in the time resolution of our own senses (if we don't use technology to aid us). Motion is a specific sensation, not a series of sequenced static sensations. Time cannot be experienced without movement, so introducing movement into a space affects our experience of time. Repetitious movements, creating a pulse, a rhythm, a beat, is something the body responds to. Technology affects perception in several ways – it extends our body in how we sense and react to the world. The microscope and telescope have done that for space, and high-speed and time-lapse cameras do it for the resolution of time. Memory is an essential part of perception too, and memory is to a large degree externalised by technology into books, sound and video recordings, pictures, and so forth. So a frequent question is: where does our own perception stop. Vision and hearing are often experienced as being linked together. This is sometimes called cross-modal perception. It turns out, according to research in neurobiology and psychology, that the process of binding sound and visual sensations is a stimulating experience in itself. It is another example of active perception. In his book *Audio-Vision* (1994), film-sound theorist Michel Chion coined the term 'synchresis' – a combination of synchronism and synthesis – to describe '(t)he spontaneous and irresistible weld produced between a particular auditory phenomenon and visual phenomenon when they occur at the same time'.[1] Sound and vision mutually influence each other, so their interplay is an important element in the creation of my work.

NA Your installations have a certain slowness. Your use of sound and composition is also quite minimal and sometimes even absent. Can you elaborate on why you choose to approach the works and composition in this manner?

HC Sometimes I shift between very rapid changes and very slow movements; sometimes between static scenes; or between very slowly changing scenes (like the *blink* projection spaces); and sometimes I use extremely slow changes, as in *Projected Light Object: Frame Series*. Lately I've been more interested in vertical compositions than in composing sequences in time. By vertical composition I mean working with layering simple loops (video, light movement, sound) of different durations to create more complex structures. I am interested in what happens if something is repeated over and over again, where time almost loses its importance. I would like to believe that the audience walks into these pockets trapped in time, and enters an extended now. Repetition turns into texture. What happens to our perception of sound, light, and movement when something is repeated? It is a very different experience to hear something the first time than to hear it over and over again. Memory of a perception influences our experience, at some point we insert ourselves into the flow, pulse or beat. To have a body is to have a presence, and memory makes the body something other than instantaneous and gives it a duration in time. An individual duration amongst other durations that beat in other rhythms. By the way, to make something go slow in the digital realm is one of the hardest things to do, and it's something I struggle with each time I make a work. It's always difficult to make a line move slowly enough, a light dim slowly enough, to make a transition that is almost invisible.

1. Michel Chion, *Audio Vision – Sound on Screen*, New York: Columbia University Press, 1994, p. 63.

THE DARK DIGITAL UNIVERSE

Interview with George Dyson

Arie Altena

George Dyson is an historian of technology. His most recent book *Turing's Cathedral: The Origins of the Digital Universe* (2012), tells the story of the group of people, led by John von Neumann at the Institute for Advanced Study in Princeton, New Jersey, who built one of the first computers with a fully electronic Random Access Memory. He also is the author of *Darwin Among the Machines* (1997), *Project Orion* (2002), and *Baidarka* (1986). Dyson was a keynote speaker at Sonic Acts in 2012, where this interview took place.

Arie Altena *Turing's Cathedral*, your book on the origin of the digital universe, was ten years in the making. It is a very precise historical account of the early development of the computer at Princeton, including the links to the clandestine hydrogen bomb project. I suppose that your book is at least partly based on original research – also considering your own background as a child. As the son of the physicist Freeman Dyson, you grew up with these scientists and engineers, and played on the campus where they worked on building this computer. How much in your book is original research?

George Dyson Everyone argues about who was first in developing a working computer. Those are endless arguments. I didn't want to establish who was first, but to understand what really happened. You can argue forever about who – or what – was first. The question of what really happened is particularly interesting, because much of it was clouded in wartime secrecy. The Americans didn't always know what the British were doing, the British didn't always know what the Americans were doing, and so on. In America we have this concept of gateway drugs. If you drink beer, it is the gateway to stronger alcohol, which is the gateway to other drugs. For me, there is a similar spectrum in research. Books are the gateway to journals, journals the gateway to archives. But the final, the really hard drug, is when you find material that isn't even in an archive, but in somebody's basement. No historian has ever seen it. This book has a lot of that. In quantity maybe one quarter of the content in the book is new, but in importance, probably half of it is based on new research. I spent a lot of time talking to people who might have things in their basements. In three cases they did. It was like finding the Dead Sea Scrolls. 'Here is the real evidence of what happened'. That was exciting. To get there takes a long time. You first have to win the confidence of the people in question.

AA On of the main characters in your book is Julian Bigelow…

GD He's the guy who built the prototype of this machine that we all use, thousands of times a day. They're everywhere. All those machines are copies of what this man built with his own hands – with the help of a half-dozen fellow engineers. But this knowledge gets lost – nobody asks anymore who actually *built* the archetype of this machine. And it could have been built very differently.

AA This is one of the fascinating aspects of *Turing's Cathedral*. Turing and Von Neumann, they had the ideas, but someone with engineering capabilities is also necessary, someone who can build the components required to assemble the machine you've imagined. Your book recounts a great story about valves – they have to be stable, and standardised, to make the machine work...

GD Or if they cannot be stable or standardised, you have to make the architecture of the machine work with bad tubes! What Bigelow's group did was quite amazing. They didn't simply engineer the computer in the sense of making the drawings and then handing them to the machine shop; first they had to build the machine shop.

AA To us the computer is an almost disembodied machine. Through the story of Bigelow you turn the attention back to engineering and it becomes clear that the computer could have been built in a different way – as you just said. Where might it have gone in a different direction?

GD Obviously, computer architecture could have gone in a number of different directions. It's an accident of history that we ended up with this particular architecture that works so well. The machine that Bigelow built runs 40 bits in parallel in the machine. At the time this was absolutely crazy. Why try to do something 40 bits at a time when you don't even know how to do it one bit at a time? But they believed they were going to get a tube called the RCA Selectron, which was an all-digital 4000-bit memory tube. They didn't get it, and they had to make a work-around. But the anticipation of the Selectron meant that the architecture was all ready for solid-state memory when it finally showed up. Solid-state memory plugs into this architecture very well. Thanks to the decision to run 40 bits in parallel, we didn't have to make a great architectural shift later. From the beginning the entire system – especially the address space – could scale, without having to change the code. Well, the code has to be changed a little, but not fundamentally. This was a very lucky accident. If we had gone for a serial architecture in the 1950s, the transition wouldn't have been so easy.

AA Is that also one of the reasons why we now work with a Von Neumann–Bigelow computer, and not with a machine derived from the Zuse Computer, or the Colossus that was built in England during the Second World War?

GD Yes. It is a bit unfair though. There is quite a strong animosity towards Von Neumann, and it is deserved in a way. One of the documents I found

– this is like a smoking gun – suggest that IBM, who hired Von Neumann as a consultant, did gain some unethical advantage over the competition. Univac, IBM's leading competition for government contracts, and the first to get a machine into actual production, had their security clearance mysteriously withheld. So IBM took the lead in producing computers, with the IBM 701, an exact copy of the machine built at IAS (Institute for Advanced Studies, Princeton). It could easily have gone the other way.

AA Though we mostly assume that the idea of artificial life started at the end of the 1980s with the first wave of interest in genetic algorithms, your book shows that right at the beginning of the Von Neumann computer, Nils Aall Barricelli came up with the idea of self-replicating code. Which is quite stunning.

GD Well, there's another thing I just found out… Although Barricelli came to Princeton in 1953, he actually tried to come in 1951. Many of these people who came to the IAS had visa problems. Barricelli was a Norwegian–Italian living in Rome. Then he moved back to Norway because of the war, and when he applied to come to the United States under the Fulbright programme, they said: your application needs to go back to Rome, because you're Italian, and the people in Rome said no you're a Norwegian and so on. He waited for two years, but the computer was also delayed, so in the end he arrived in 1953, and it turned out to be the right time...

AA How did Barricelli's idea of replicating code originate?

GD He was thinking about genetics – this was even before Watson–Crick discovered the structure of DNA. He was doing experiments by hand on graph paper with numbers. Somehow he heard that Von Neumann was building a computing machine. So he wrote him in 1951 saying 'I want to come and use this machine'.

AA Because it calculated faster?

GD Yes. And Von Neumann answered, after doing some rough calculations, that he could have so-and-so much time. I just met someone who knew Barricelli very well. That was frustrating for me, because it was after the book was finished. We think that exchanging genetic information between organisms by computers must be some a completely new and very difficult technical problem. But in the last few years biology is learning that micro-organisms have been doing this all along. There are viruses and bacteria that more or less store their genetic information out 'in the cloud'. It turns out that you can remove half the genetic sequences of some of these microbes, and they will rebuild it by taking it back from the environment through viruses. The viruses represent a library of genetic sequences. It's a very interesting concept, and it seems that life, in computing terms, has the API, the application programming interface, to do remote accessing of cloud-based sequences. So the fact that we start doing this with computers, from the point of view of the cell, is not entirely new.

AA In your book you show that it somehow all came together around the same time: the building of the machine, the idea of using code, Watson and Crick's idea of DNA and how DNA codes life. You describe this as the birth of the digital universe, yet one could also say that for human beings a new era started.

GD You can look at this question on many different levels. The higher level is to look from the level of life in general. Life developed by taking advantage of self-replicating molecules, which it used as a tool to convey its information. Life is always looking for new opportunities.

Instead of taking the perspective of us using computers, you can look at it as life itself storing information in computers rather than in DNA, because it transmits faster. The animal or the plant that is able to spread its seeds the fastest and the widest wins. The life forms that propagate the best are going to use computers as a vehicle for genetic coding, because computers transmit faster. This could be good or bad, but it's not science fiction, it is actually happening.

AA Only in the case of computers it happens in a different universe.

GD Yes. On the dark side, this means that computational intelligence is learning how to operate life. You want to be careful...

AA You could also say that we found out there is more of an interaction between those two universes.

GD They are co-operating. We are no longer the top intelligence. We evolved in a world we didn't really understand. The forces of nature were greater than us. In a way we are returning to that world. We know these machines no better than we know ourselves.

AA The history of the computer is closely connected to the idea of controlling the forces of nature. One of the things that has been there from the beginning is the idea of modelling the weather, and being able to control it, just as it's also the history of being able to control the hydrogen bomb. It's a story about control...

GD The Von Neumann computer project began with an interest in predicting the weather in order to control it. Of course the government was very happy to fund that. One question that, historically speaking, I haven't answered, is that there seems to be good reason to believe that the weather prediction project was a smoke screen for the development of the hydrogen bomb. They had to do the calculations for the hydrogen bomb, but these had to be secret. Von Neumann was so clever, he could take the same machine and the same mathematics.... Let's say we're working on the weather, and we'll use the calculations for the bomb. He wanted to do both, and he did do both. He was very successful at it. The fact that you can give a five-day forecast now, is based on the same codes and the same models developed 60 years ago. Something I didn't notice at first is that they worked on five main problems that were mathematically similar, but on completely different time scales. The bomb explosions were over in millionths of a second; the shockwave was seconds to minutes; weather prediction was hours to days; biological evolution was hundreds of thousands of years; and then they worked on the evolution of stars, which is on the timescale of the age of solar system. It is an amazing span of time. And then I put that on a graph, to see how it was spaced and see what it represented. Our human attention span is right exactly in the middle. Why are we right in the middle of this?

AA We can see as far as our instruments allow us to see, which is much further than our eyes can see. Does that relate in any way to the history of the computer?

GD It does, because these very short and very long intervals of time might otherwise not have been accessible to us. In terms of human survival the more important thing may be to keep track of things that are very slow. We are worried about what the climate is going to be like in a hundred years or more, and now we have a way of knowing that. I think we are overly focused on fast things and not enough on the slow processes. A system that takes long-term effects into account would be better for us. We need slow calculation.

The IBM Blue Gene/P supercomputer installation at the Argonne Leadership Angela Yang Computing Facility located in the Argonne National Laboratory, in Lemont, Illinois, USA.

AA Politics is not really doing that...

GD Obviously our political system is a failure right now. No one seems to question that political leadership is failing in all countries. There is a connection between failing political leadership and computation. The real leadership no longer comes from politics – there are no politicians like Pierre Trudeau and John Diefenbaker any more. It comes from Google. It is based on money. This is scary. This is what the VPRO television documentary, *Money and Speed, Inside the Black Box* was about as well. The financial forces are huge. I think it is important to recognise how many of our social problems originate in computerisation.

AA The documentary shows that a part of the financial markets is 'ruled' by algorithms. Our human idea of a stock market is that it is based on investments in the future, on the idea that something is going to be different – better – in two years time or more. The algorithm that trades and acts on strange behaviour in the computer model doesn't know time or future. That's also one of the things your book is about, the idea that human time is completely different from time in a digital universe. Could you explain that?

GD That is one of the most profound things, and if you understand it, you also understand why the world is so confused right now. I think one of the largest misunderstandings is the belief that your computer has a clock. What is the clock's speed? Well, maybe your computer's clock is 1.2 GHz and mine is 2.4 GHz, so mine is twice as fast as yours. But it isn't a clock. In our world a clock measures intervals of time, but the 'clock' that is in your computer only regulates the sequence of steps in performing a computation. It happens to have a certain speed – but it keeps speeding up, and its only purpose is to ensure that two things never happen at the same time. On the Bigelow machine the speed was not fixed. You could go slower and faster. But in the computer world, there is no time. There is only what happens next. It's just how fast the electrons move. Every year sees a new machine that is twice as fast. That's why time in the digital universe is completely disconnected from ours. And that's why the digital world, from our point of view, seems to be speeding up. From the point of view of the digital world it is the opposite: if you looked at our world from the digital world, everything is slowing down. Computers might ask: 'Why are people getting slower and slower? Why don't they do anything? Each time I looked the humans gave me more instructions, but now I'm waiting and waiting. He still hasn't typed the next letter'. The human and the digital are two worlds on completely different time scales. That's the huge transformation that is going on. When we don't give instructions to the computer, they go to sleep. The idea of cloud computing is a way of using that empty time. The huge server farms that are being built – the ones that have their own power plants – aren't sitting around waiting, they're doing stuff. What they're doing is similar to dreaming. When we go to sleep, our brains don't shut down, they process and dream. That's why Google is so efficient, because they use all their machines all the time.

AA Why has our understanding of computation, and our engineering competence declined so much? If indeed it has declined?

GD In my experience it has declined more in craftsmanship than in engineering. In America we have largely stopped teaching how to use tools. For someone like me this is very sad. Not many young people know how to use a chainsaw. These skills are exchanged for skills in handling things like iPhones, which are strange objects that somehow work, but when they stop working you get a new one. From my point of view it is important to understand what you use, so you don't hand over all the power to machines.

AA Could you envision ways in which empowerment is restored to our relationships with technology and machines?

GD Yes. There is a very active movement of people who still do programming at deep levels. There are still people who do understand the code, perhaps not on the Von Neumann level, but at least on a Unix level. We need those people. On the hardware level however the knowledge is disappearing. We are now at the point where if a machine fails, it knows itself what it needs: I need a new motherboard. If it needs more than that, we throw it away. We don't fix computers anymore. Years ago Google reached a point where they were adding something like 30 new machines a day without throwing the dead ones away – they only added new ones. That was a huge transition. It was much cheaper to just add new cells than clean up old ones. Who knows what those machines are doing now.

AA Where could all of this lead?

GD I don't know. But we don't have to wait that long to find out. You can think of a number of science fiction scenarios. The obvious one is that the system collapses, and nobody can even find food without their iPhone telling them where to look. We'll lose 98% of the global population, et cetera. That's the scariest one. Another one is a sort of H.G. Wells story, where the machines keep everyone happy. The people programming and taking care of the computers are all doing really well, while the rest of the people suffer. This is going to diverge into a situation where a certain number of people propagate the machines and the rest of the people are put away as being unnecessary. That is scary. Then there is the scenario that we start losing our intelligence because we don't really need it. The machines don't need intelligent people; they just need people to be content with taking care of their basic machine needs. That's scary as well. Then there's a happy possibility that we'll have more free time and wealth and we'll use it carefully, and that the globalisation of computing ends war. That's possible too, as this is a very different world from the world of 50 years ago.

AA What would the computer dream of, if it is dreaming in the way you just suggested?

GD I have no idea!

AA Could we find out?

GD Good question! There is a plausible theory that dreaming came first, and consciousness followed later. It assumes we were born dreaming and eventually matched the reality to the dream. And when we go to sleep we return to dreaming. It may well be the same with machine intelligence. What it does in its spare time is where the machine's consciousness will arise, not from something we programmed.

	Current Official Name of Satellite	Operator/Owner	Country of Operator/Owner	Users (C - Commercial, G - Government, Civ - Civil, M - Military)	Purpose	Class of Orbit	Launch Mass (kg.)	Year
764	RapidEye-4	RapidEye AG	Germany	C	Earth Observation	LEO	175	2008
765	RapidEye-5	RapidEye AG	Germany	C	Earth Observation	LEO	175	2008
766	RASAT	Space Technologies Institute	Turkey	G	Earth Observation	LEO	113	2011
767	Rascom-QAF1R	RASCOM Africa	Multinational	C	Communications	GEO	3,050	2010
768	RAX-2	University of Michigan	USA	Civ	Space Science	LEO	3	2011
769	RazakSat	National Space Agency	Malaysia	G	Remote Sensing	LEO	180	2009
770	RE	NRO	USA	M	Remote Sensing	LEO	3	2012
771	INDEX	ISAS/JAXA	Japan	G	Tech Development	LEO	70	2005
772	Resourcesat2	ISRO	India	G	Earth Observation	LEO	1,206	2011
773	Resurs-DK1	TsSKB Progress	Russia	G/C	Earth Observation	LEO	6,650	2006
774	RISat-1	Ministry of Defense	India	M	Surveillance	LEO	1,858	2012
775	RISat-2	Ministry of Defense	India	M	Surveillance	LEO	93	2009
776	Cosmos 2416	Ministry of Defense	Russia	M	Communications	LEO	225	2005
777	Cosmos 2481	Russian Defense Ministry	Russia	M	Communications	LEO	280	2012
778	Cosmos 2437	Russian Defense Ministry	Russia	M	Communications	LEO	280	2008
779	Cosmos 2438	Russian Defense Ministry	Russia	M	Communications	LEO	280	2008
780	Cosmos 2439	Russian Defense Ministry	Russia	M	Communications	LEO	280	2008
781	Cosmos 2451	Russian Defense Ministry	Russia	M	Communications	LEO	280	2009
782	Cosmos 2452	Russian Defense Ministry	Russia	M	Communications	LEO	280	2009
783	Cosmos 2453	Russian Defense Ministry	Russia	M	Communications	LEO	280	2009
784	Rumba	European Space Agency	ESA	G	Space Physics	Ell	1,200	2000
785	SAC-C	CONAE	Multinational	Civ	Research	LEO	485	2000
786	SAC-D	Argentina/NASA	Argentina/USA	G	Earth Observation	LEO	1,600	2011
787	Salsa	European Space Agency	ESA	G	Space Physics	Ell	1,200	2000
788	Samba	European Space Agency	ESA	G	Space Physics	Ell	1,200	2000
789	SAR-Lupe 1	German Federal Armed Forces	Germany	M	Surveillance	LEO	770	2006
790	SAR-Lupe 2	German Federal Armed Forces	Germany	M	Surveillance	LEO	770	2007
791	SAR-Lupe 3	German Federal Armed Forces	Germany	M	Surveillance	LEO	770	2007
792	SAR-Lupe 4	German Federal Armed Forces	Germany	M	Surveillance	LEO	770	2008
793	SAR-Lupe 5	German Federal Armed Forces	Germany	M	Surveillance	LEO	770	2008
794	Satmex 4	Satellites Mexicanos S.A.	Mexico	C	Communications	GEO	2,276	1994
795	Satmex 5	Satellites Mexicanos S.A.	Mexico	C	Communications	GEO	3,542	1998
796	Satmex 6	Satellites Mexicanos S.A.	Mexico	C	Communications	GEO	5,456	2006
797	Saudicomsat1	Riyadh Space Research Inst	Saudi Arabia	C	Tech Development	LEO	12	2004
798	Saudicomsat2	Riyadh Space Research Inst	Saudi Arabia	C	Tech Development	LEO	12	2004
799	Saudicomsat3	Riyadh Space Research Inst	Saudi Arabia	C	Communications	LEO	12	2007
800	Saudicomsat4	Riyadh Space Research Inst	Saudi Arabia	C	Communications	LEO	12	2007
801	Saudicomsat5	Riyadh Space Research Inst	Saudi Arabia	C	Communications	LEO	12	2007
802	Saudicomsat6	Riyadh Space Research Inst	Saudi Arabia	C	Communications	LEO	12	2007
803	Saudicomsat7	Riyadh Space Research Inst	Saudi Arabia	C	Communications	LEO	12	/2007
804	Saudisat 1C	King Abdulaziz City	Saudi Arabia	G	Research	LEO	10	2002
805	Saudisat-2	Riyadh Space Research Inst	Saudi Arabia	G	Research	LEO	35	2004
806	Saudisat-3	Riyadh Space Research Inst	Saudi Arabia	G	Research	LEO	200	2007
807	USA 230	US Air Force	USA	M	Early Warning	GEO	4,500	2011
808	USA 216	Space Surveillance Network	USA	M	Reconnaissance	LEO	1,031	2010
809	USA 160	NRO/US Navy	USA	M	Surveillance/Ocean	LEO	5,000+	2001
810	USA 160	NRO/US Navy	USA	M	Surveillance/Ocean	LEO	5,000+	2001
811	USA 173	NRO/US Navy	USA	M	Surveillance/Ocean	LEO	5,000+	2003
812	USA 173	NRO/US Navy	USA	M	Surveillance/Ocean	LEO	5,000+	2003
813	USA 181	NRO/US Navy	USA	M	Surveillance/Ocean	LEO	5,000+	2005
814	USA 181	NRO/US Navy	USA	M	Surveillance/Ocean	LEO	5,000+	2005
815	USA 194	NRO/US Navy	USA	M	Surveillance/Ocean	LEO	5,000+	2007
816	USA 194	NRO/US Navy	USA	M	Surveillance/Ocean	LEO	5,000+	2007
817	USA 229	NRO/US Navy	USA	M	Surveillance/Ocean	LEO	5,000+	2011
818	USA 229	NRO/US Navy	USA	M	Surveillance/Ocean	LEO		2011
819	USA 238	NRO/US Navy	USA	M	Surveillance/Ocean	LEO	6,500	2012
820	USA 238	NRO/US Navy	USA	M	Surveillance/Ocean	LEO	6,500	2012
821	SCD-1	INPE	Brazil	G	Meteorology	LEO	110	1993
822	SCD-2	INPE	Brazil	G	Meteorology	LEO	110	1998
823	Scisat-1	Canadian Space Agency	Canada	G	Space Science	LEO	150	2003
824	SDO	NASA	USA	G	Space Science	GEO	3,100	2010
825	USA 155	NRO	USA	M	Surveillance	GEO		2000
826	USA 162	NRO/US Air Force	USA	M	Communications	GEO		2001
827	USA 179	NRO/US Air Force	USA	M	Communications	Ell		2004
828	USA 198	NRO/US Air Force	USA	M	Communications	Ell		2007
829	USA 227	NRO/US Air Force	USA	M	Communications	GEO		2011

INSTITUTES / COMPANIES

number of orbiting satellites

830	USA 236	NRO/US Air Force	USA	M	Surveillance	GEO		2012
831	SDS-4	JAXA	Japan	G	Tech Development	LEO	50	2012
832	SEEDS 2	Nihon University	Japan	Civ	Tech Development	LEO	3	2008
833	SES-1	SES World Skies	USA	C	Communications	GEO		2010
834	SES-2	SES World Skies	USA	C	Communications	GEO	3,200	2011
835	SES-3	SES World Skies	USA	C	Communications	GEO	3,112	2011
836	SES-4	SES World Skies	USA	C	Communications	GEO		2012
837	SES-5	SES World Skies	USA	C	Communications	GEO	6,007	2012
838	SES-7	SES World Skies	USA	C	Communications	GEO	4,007	2009
839	SESAT-1	EUTELSAT	Multinational	C	Communications	GEO	2,500	2000
840	Shijian 1101	CAST	China (PR)	G	Space Physics	LEO		2009
841	Shijian 1102	CAST	China (PR)	G	Tech Development	LEO		2011
842	Shijian 1103	CAST	China (PR)	G	Tech Development	LEO		2011
843	Shijian 12	CAST	China (PR)	G	Tech Development	LEO		2010
844	Shijian 6A	CAST	China (PR)	G	Space Physics	LEO		2004
845	Shijian 6B	CAST	China (PR)	G	Space Physics	LEO		2004
846	Shijian 6C	CAST	China (PR)	G	Space Physics	LEO		2006
847	Shijian 6D	CAST	China (PR)	G	Space Physics	LEO		2006
848	Shijian 6E	CAST	China (PR)	G	Space Physics	LEO		2008
849	Shijian 6F	CAST	China (PR)	G	Space Physics	LEO		2008
850	Shijian 6G	CAST	China (PR)	G	Reconnaissance	LEO		2010
851	Shijian 6H	CAST	China (PR)	G	Reconnaissance	LEO		2010
852	Shijian 7	CAST	China (PR)	G	Space Physics	LEO		2005
853	Shijian 9A	CAST	China (PR)	G	Tech Development	LEO		2012
854	Shijian 9B	CAST	China (PR)	G	Tech Development	LEO		2012
855	Shiyan 1	CAST	China (PR)	G	Remote Sensing	LEO	204	2004
856	Shiyan 3	CAST	China (PR)	G	Remote Sensing/	LEO	300	2008
857	Shiyan 4	CAST	China (PR)	G	Remote Sensing	LEO	300	2011
858	Sich 2	NKAU	Ukraine	G	Earth Observation	LEO	169	2011
859	Sicral 1A	Italian Defense Ministry	Italy	M	Communications	GEO	2,596	2001
860	Sicral 1B	Defense Ministry/Telespazio	Italy	M/C	Communications	GEO	3,038	2009
861	Sina-1	IROST	Iran	G	Research	LEO	170	2005
862	Sinosat-1	Direct Broadcast Satellite	China (PR)	C	Communications	GEO	2,840	1998
863	Sinosat-5C	Eutelsat	Multinational	C	Communications	GEO	2,200	2007
864	Sinosat-6	Direct Broadcast Satellite.	China (PR)	C	Communications	GEO	5,000	2010
865	Sirius-1	Sirius Satellite Radio	USA	C	Communications	Ell	3,727	2000
866	Sirius 2	Sirius Satellite Radio	USA	C	Communications	Ell	3,792	2000
867	Sirius 3	Sirius Satellite Radio	USA	C	Communications	Ell	3,727	2000
868	Sirius 4	SES Sirius AB	Sweden	C	Communications	GEO	4,400	2007
869	Sirius FM-5	Sirius XM Radio, Inc.	USA	C	Communications	GEO	5,800	2009
870	Sirius XM-5	Sirius XM Radio, Inc.	USA	C	Communications	GEO	5,983	2010
871	Skynet 4C	Intelsat/EADS	United Kingdom	M	Communications	GEO	1,474	1990
872	Skynet 4E	Ministry of Defence	United Kingdom	M	Communications	GEO	1,510	1999
873	Skynet 4F	Ministry of Defence	United Kingdom	M	Communications	GEO	1,510	2001
874	Skynet 5A	Intelsat/EADS	United Kingdom	M	Communications	GEO	4,700	2007
875	Skynet 5B	Intelsat/EADS	United Kingdom	M	Communications	GEO	4,635	2007
876	kynet 5C	Ministry of Defence	United Kingdom	M	Communications	GEO	4,600	2008
877	SkyTerra 1	LightSquared	USA	C	Communications	GEO	5,360	2010
878	USA 119	NRO	USA	M	Communications	Ell		1996
879	SMDC-ONE 1.1	U.S.Army Space and Missile	USA	M	Tech Development	LEO	5	2012
880	SMDC-ONE 1.2	U.S.Army Space and Missile	USA	M	Tech Development	LEO	3	2012
881	SMOS	CNES/European Space Agency	ESA	G	Earth Observation	LEO	658	2009
882	SOHLA 1	Astrotech SOHLA	Japan	Civ	Tech Development	LEO	50	2009
883	SORCE	NASA/Univ. of Colorado	USA	G/C	Astrophysics	LEO	315	2003
884	Spaceway 3	Hughes Network Systems	USA	C	Communications	GEO	6,100	2007
885	Spaceway F1	DirecTV, Inc.	USA	C	Communications	GEO	5,993	2005
886	Spaceway F2	DirecTV, Inc.	USA	C	Communications	GEO	5,993	2005
887	Spainsat	Hisdesat/Ministry of Defense	Spain	M	Communications	GEO	3,680	2006
888	Spektr-R	Astron/Academy of Sciences	Multinational	G	Astrophysics	Ell	3,660	2011

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Secure communications satellite for Spanish Ministry of Defense: both X and Ku-band.

889	SPIRALE-A	Ministry of Defense/DGA	France	M	Tech Development	Ell	117	2009
890	SPIRALE-B	Ministry of Defense/DGA	France	M	Tech Development	Ell	117	2009
891	Spot 5	Spot Image	FR/BE/SE	C	Earth Observation	LEO	3,030	2002
892	Spot 6	Spot Image	FR/BE/SE	C	Earth Observation	LEO	720	2012
893	SRMSat	SRM University	India	Civ	Tech Development	LEO	11	2011
894	SSOT	Chilean Air Force	Chile	G/M	Earth Observation	LEO	117	2011
895	ST-1	SingTel/Chunghwa Telecom	Singapore/Taiwan	C	Communications	GEO	3,255	1998
896	ST-2	SingTel/Chunghwa Telecom	Singapore/Taiwan	C	Communications	GEO	5,090	2011
897	Star 1 C1	Star One SES	Brazil	C	Communications	GEO	4,100	2007
898	Star 1 C2	Star One SES	Brazil	C	Communications	GEO	4,100	2008
899	Star 1 C3	Star One SES	Brazil	C	Communications	GEO	3,225	2012
900	USA 217	USAF Space Test Program	USA	M	Tech Development	LEO	180	2010
901	Cosmos 2384	Ministry of Defense	Russia	M	Communications	LEO	225	2001
902	Cosmos 2385	Ministry of Defense	Russia	M	Communications	LEO	225	2001
903	Cosmos 2386	Ministry of Defense	Russia	M	Communications	LEO	225	2001
904	Cosmos 2390	Ministry of Defense	Russia	M	Communications	LEO	225	2002
905	Cosmos 2391	Ministry of Defense	Russia	M	Communications	LEO	225	2002
906	Cosmos 2400	Ministry of Defense	Russia	M	Communications	LEO	225	2003
907	Cosmos 2401	Ministry of Defense	Russia	M	Communications	LEO	225	2003
908	Cosmos 2408	Ministry of Defense	Russia	M	Communications	LEO	225	2004
909	Cosmos 2409	Ministry of Defense	Russia	M	Communications	LEO	225	2004
910	Cosmos 2467	Ministry of Defense	Russia	M	Communications	LEO	225	2010
911	Cosmos 2468	Ministry of Defense	Russia	M	Communications	LEO	225	2010
912	USA 205	Missile Defense Agency (MDA)	USA	M	Tech Development	LEO		2009
913	USA 208	Missile Defense Agency (MDA)	USA	M	Tech Development	LEO	2,240	2009
914	USA 209	Missile Defense Agency (MDA)	USA	M	Tech Development	LEO	2,240	2009
915	STUDSat	TeamStudSat	India	Civ	Tech Development	LEO	1	2010
916	Superbird 7	Sky Perfect JSAT Corporation	Japan	C	Communications	GEO	5,000	2008
917	Superbird-B2	Sky Perfect JSAT Corporation	Japan	C	Communications	GEO	4,051	2000
918	Superbird-C	Sky Perfect JSAT Corporation	Japan	C	Communications	GEO	3,130	1997
919	Suzaku	JAXA/NASA	Japan/USA	G	Astrophysics	LEO	1,600	2005
920	Swift	Goddard/Penn State Uni	USA/UK/IT	G/C	Astrophysics	LEO	1,463	2004
921	SwissCube	EPFL	Switzerland	Civ	Tech Development	LEO	1	2009
922	Syracuse 3A	Defense Ministry	France	M	Communications	GEO	3,725	2005
923	Syracuse 3B	Defense Ministry	France	M	Communications	GEO	3,750	2006
924	TacSat 4	Naval Research Laboratory	USA	M	Tech Development	Ell	450	2011
925	TanDEM-X	DLR/Astrium	Germany	G	Earth Observation	LEO	1,350	2010
926	Tango	European Space Agency	ESA	G	Space Physics	Ell	1,200	2000
927	TDRS-10	NASA	USA	G	Communications	GEO	3,180	2002
928	TDRS-3	NASA	USA	G	Communications	GEO	3,180	1988
929	TDRS-5	SES Americom SES	USA	G/C	Communications	GEO	3,180	1991
930	TDRS-6	NASA/SES Americom SES	USA	G/C	Communications	GEO	3,180	1993
931	TDRS-7	NASA	USA	G	Communications	GEO	3,180	1995
932	TDRS-8	NASA	USA	G	Communications	GEO	3,180	2000
933	TDRS-9	NASA	USA	G	Communications	GEO	3,180	2002
934	TecSAR	Defense Ministry	Israel	M	Reconnaissance	LEO	300	2008
935	Telkom 1	PT Telkomunikasi	Indonesia	C	Communications	GEO	2,763	1999
936	Telkom 2	PT Telkomunikasi	Indonesia	C	Communications	GEO	1,930	2005
937	Telstar 11N	Telesat Canada Ltd.	Canada	C	Communications	GEO	4,010	2009
938	Telstar 12	Eutelsat	Multinational	C	Communications	GEO	3,878	1999
939	Telstar 14R	Telesat Canada Ltd	Canada	C	Communications	GEO	4,970	2011
940	Telstar 18	Loral/APT	Multinational	C	Communications	GEO	4,640	2004
941	TerraSAR X 1	DLR/Infoterra	Germany	G/C	Remote Sensing	LEO	1,230	2007
942	TerraStar 1	TerraStar Corporation	USA	C	Communications	GEO	6,910	2009
943	TES	TES	India	G/M	Reconnaissance	LEO	1,108	2001
944	TET-1	German Aerospace Center	Germany	C	Tech Development	LEO	120	2012
945	Thaicom-4	Thaicom Public Company Ltd.	Thailand	C	Communications	GEO	6,505	2005
946	Thaicom-5	Thaicom Public Company Ltd.	Thailand	C	Communications	GEO	2,800	2006
947	THEMIS A	NASA/Univ of California	Multinational	G/C	Space Physics	Ell	126	2007
948	THEMIS D	NASA/Univ of California	Multinational	G/C	Space Physics	Ell	126	2007
949	THEMIS E	NASA/Univ of California	Multinational	G/C	Space Physics	Ell	126	2007
950	Theos	GISTDA	Thailand	G	Earth Observation	LEO	750	2008
951	Thor-2	Telenor Sat Broadcasting	Norway	C	Communications	GEO	1,400	1997
952	Thor-3	Telenor Sat Broadcasting	Norway	C	Communications	GEO	1,400	1998
953	Thor-5	Telenor Sat Broadcasting	Norway	C	Communications	GEO	2,024	2008
954	Thor-6	Telenor Sat Broadcasting	Norway	C	Communications	GEO	3,050	2009
955	Thuraya 2	Thuraya Sat Communications	United Arab Emirates	C	Communications	GEO	5,250	2003
956	Thuraya 3	Thuraya Sat Communications	United Arab Emirates	C	Communications	GEO	5,180	2008
957	Tian Xun-1	Nanjing University	China (PR)	Civ	Tech Development	LEO	35	2011
958	Tiangong-1	Beijing Aerospace	China (PR)	G	Tech Development	LEO	8,506	2011
959	Tianhui 1-01	CASTC	China (PR)	G	Earth Observation	LEO	2,500	2010
960	Tianhui 1-02	CASTC	China (PR)	G	Earth Observation	LEO	2,500	2012
961	TianLian 1	CAST	China (PR)	G	Communications	GEO	3,750	2008
962	TianLian 2	CAST	China (PR)	G	Communications	GEO	2,250	2011
963	TianLian 3	CAST	China (PR)	G	Communications	GEO	2,200	2012

964	Tiantuo 1	National University	China (PR)	G	Tech Development	LEO	9	2012
965	TIMED	NASA/Johns Hopkins	USA	G/C	Astrophysics	LEO	587	2001
966	TISat-1	Scuola Universitaria	Switzerland	Civ	Tech Development	LEO	1	2010
967	Topsat	Ministry of Defence	United Kingdom	G	Tech Development	LEO	120	2005
968	TRMM	NASA/JAXA	Japan/USA	G	Earth Observation	LEO	3,820	1997
969	USA 136	NRO/USAF	USA	M	E.Surveillance	Ell	8,000	1997

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Signals intelligence: surveillance of cellular phones.

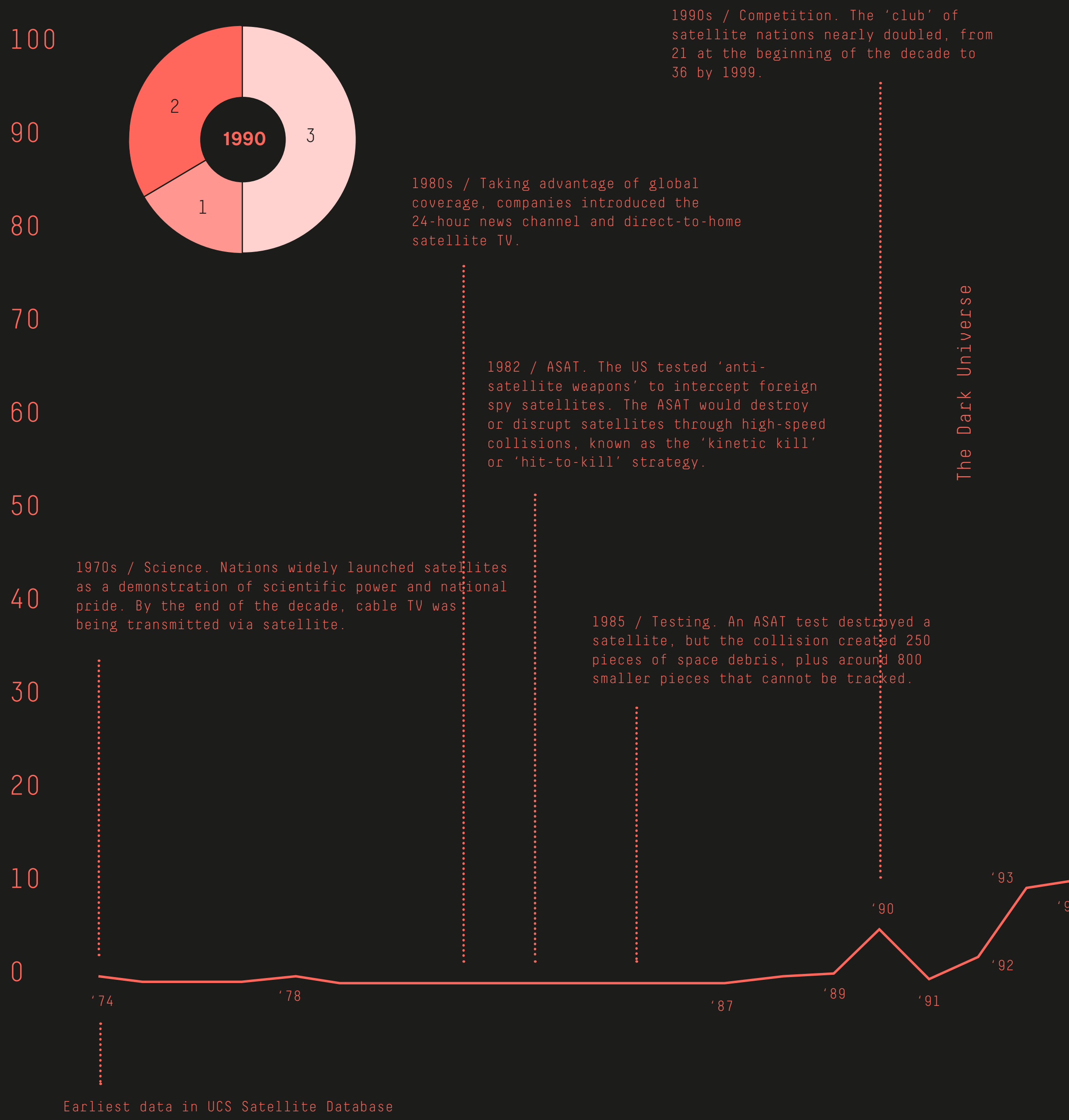
970	Cosmos 2428	Ministry of Defense	Russia	M	E. surveillance	LEO	3,200	2007
971	Turksat 3A	Turksat	Turkey	C	Communications	GEO	3,100	2008
972	USA 146	US Navy	USA	M	Communications	GEO	3,200	1999
973	USA 174	US Navy	USA	M	Communications	GEO	3,200	2003
974	USA 95	US Navy	USA	M	Communications	GEO	3,200	1993
975	USA 108	US Navy	USA	M	Communications	GEO	3,200	1995
976	USA 114	US Navy	USA	M	Communications	GEO	3,200	1995
977	USA 127	US Navy	USA	M	Communications	GEO	3,200	1996
978	USA 138	US Navy	USA	M	Communications	GEO	3,206	1998
979	UK-DMC-2	UK/DMCII	United Kingdom	G	Earth Observation	LEO	97	2009
980	Unisat-3	La Sapienza Uni of Rome	Italy	Civ	Sci Research	LEO	12	2004
981	Cosmos 2479	Ministry of Defense	Russia	M	Early Warning	GEO	2,400	2012
982	Cosmos 2422	Ministry of Defense	Russia	M	Early Warning	Ell	2,400	2006
983	Cosmos 2446	Ministry of Defense	Russia	M	Early Warning	Ell	2,400	2008
984	Cosmos 2469	Ministry of Defense	Russia	M	Early Warning	Ell	2,400	2010
985	RBSP-A	NASA/Johns Hopkins	USA	G	Earth Science	Ell	648	2012
986	RBSP-B	NASA/Johns Hopkins	USA	G	Earth Science	Ell	666	2012
987	VeneSat 1	Ministry of Science	Venezuela	G	Communications	GEO	5,100	2008
988	Vesselsat-1	ORBCOMM Inc.	USA	C	Maritime Tracking	LEO	29	2011
989	Vesselsat-2	ORBCOMM Inc.	USA	C	Maritime Tracking	LEO	29	2012
990	ViaSat-1	ViaSat, Inc.	USA	C	Communications	GEO	6,740	2011
991	Vinasat 1	VNPT	Vietnam	G	Communications	GEO	2,600	2008
992	Vinasat 2	VNPT	Vietnam	G	Communications	GEO	2,970	2012
993	VRSS-1	Agency for Space Activities	Venezuela	Go	Remote Sensing	LEO	880	2012
994	USA 195	US Air Force	USA	M	Communications	GEO	5,900	2007
995	USA 204	US Air Force	USA	M	Communications	GEO	5,987	2009
996	USA 211	US Air Force	USA	M	Communications	GEO	5,990	2009
997	USA 233	US Air Force	USA	M	Communications	GEO	5,990	2012
998	WildBlue 1	WildBlue Communications	USA	C	Communications	GEO	4,735	2006
999	Wind	NASA	Multinational	G	Astrophysics	Ell	1,200	1994
1000	Worldview 1	DigitalGlobe Corporation	USA	M/C	Earth Observation	LEO	4,500	2007
1001	Worldview 2	DigitalGlobe Corporation	USA	M/C	Earth Observation	LEO	2,800	2009
1002	XaTcobeo	University of Vigo	Spain	Civ	Tech Development	LEO	1	2012
1003	Xinyan 1	DFH Satellite	China (PR)	G	Tech Development	LEO		2012
1004	XM 3	XM Satellite Radio	USA USA	C	Communications	GEO	4,703	2005
1005	XM 4	XM Satellite Radio USA	USA	C	Communications	GEO	5,193	2006
1006	XM 2	XM Satellite Radio USA	USA	C	Communications	GEO	4,682	2001
1007	XM 1	XM Satellite Radio USA	USA	C	Communications	GEO	4,667	2001
1008	XMM Newton	ESOC	ESA	G	Space Physics	Ell	3,764	1999
1009	X-Sat	CREST	Singapore	G	Earth Observation	LEO	91	2011
1010	XTAR-EUR	Ministry of Defense/XTAR	Spain	M/G	Communications	GEO	3,631	2005
1011	XW-1	DFH Satellite/AMSAT-China	China (PR)	Civ	Communications	LEO	60	2009
1012	Yahsat-1A	YAHSAT	United Arab Emirates	M/C	Communications	GEO	5,953	2011
1013	Yahsat-1B	YAHSAT	United Arab Emirates	M/C	Communications	GEO	6,000	2012
1014	Yamal-201	Gazprom Space Systems	Russia	C	Communications	GEO	1,360	2003
1015	Yamal-202	Gazprom Space Systems	Russia	C	Communications	GEO	1,320	2003
1016	Yamal-300K	Gaxprom Space Systems	Russia	C	Communications	GEO	1,640	2012
1017	Yaogan 10	People's Liberation Army	China (PR)	M	Remote Sensing	LEO		2010
1018	Yaogan 11	People's Liberation Army	China (PR)	M	Remote Sensing	LEO		2010
1019	Yaogan 12	People's Liberation Army	China (PR)	M	Remote Sensing	LEO		2011
1020	Yaogan 13	People's Liberation Army	China (PR)	M	Remote Sensing	LEO		2011

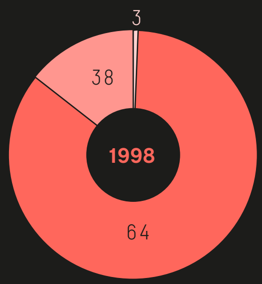
SATELLITE LAUNCHES

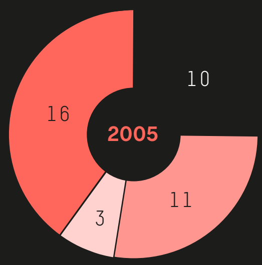
number by year

Number of satellite users

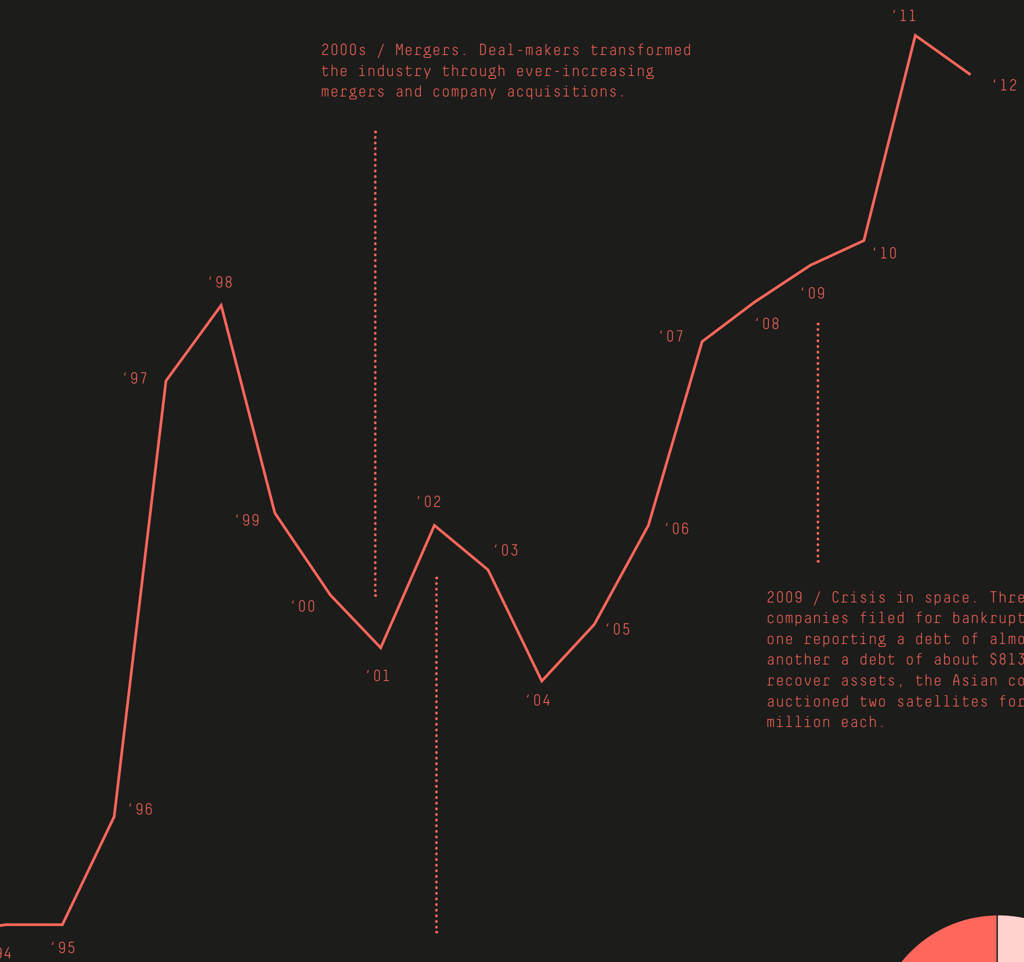
- Government
- Military
- Civil
- Commercial





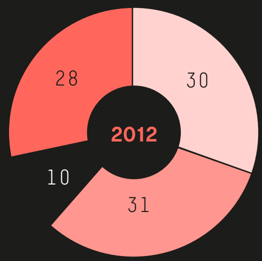


2000s / Mergers. Deal-makers transformed the industry through ever-increasing mergers and company acquisitions.



2009 / Crisis in space. Three larger companies filed for bankruptcy protection, one reporting a debt of almost $2 billion, another a debt of about $813 million. To recover assets, the Asian company Protostar auctioned two satellites for around $200 million each.

2002 / Jamming. As an 'anti-satellite weapon' (ASAT), satellite jamming interferes with radio communications between a satellite and users on the ground. US and Russian jamming capabilities are suspected of being able to reach geostationary orbit.



1021	Yaogan 14	People's Liberation Army	China (PR)	M	Remote Sensing	LEO		2012
1023	Yaogan 15	People's Liberation Army	China (PR)	M	Remote Sensing	LEO	1,040	2012
1024	Yaogan 16A	People's Liberation Army	China (PR)	M	Remote Sensing	LEO		2012
1025	Yaogan 16B	People's Liberation Army	China (PR)	M	Remote Sensing	LEO		2012
1026	Yaogan 16C	People's Liberation Army	China (PR)	M	Remote Sensing	LEO		2012
1027	Yaogan 2	People's Liberation Army	China (PR)	M	Remote Sensing	LEO	1,200	2007
1028	Yaogan 3	People's Liberation Army	China (PR)	M	Remote Sensing	LEO	2,700	2007
1029	Yaogan 4	People's Liberation Army	China (PR)	G	Remote Sensing	LEO	2,700	2008
1030	Yaogan 5	People's Liberation Army	China (PR)	G	Remote Sensing	LEO	2,700	2008
1031	Yaogan 6	People's Liberation Army	China (PR)	G	Remote Sensing	LEO	1,800	2009
1032	Yaogan 7	People's Liberation Army	China (PR)	G	Remote Sensing	LEO	2,700	2009
1033	Yaogan 8	People's Liberation Army	China (PR)	G	Remote Sensing	LEO		2009
1034	Yaogan 9A	People's Liberation Army	China (PR)	G	Remote Sensing	LEO		2010
1035	Yaogan 9B	People's Liberation Army	China (PR)	G	Remote Sensing	LEO		2010
1036	Yaogan 9C	People's Liberation Army	China (PR)	G	Remote Sensing	LEO		2010
1037	Youthsat	ISRO	India	G	Scien Research	LEO	92	2011
1038	Yubileiny	NILAKT ROSTO	Russia	Civ	Tech Development	LEO	45	2008
1039	Ziyuan 2B	Academy of Space Technology	China (PR)	M	Remote Sensing	LEO	1,500	2002
1040	Ziyuan 2C	Academy of Space Technology	China (PR)	M	Reconnaissance	LEO		2004
1041	ZP-1B	Zhejiang University	China (PR)	Civ	Sci Research	LEO	4	2010
1042	ZP-1C	Zhejiang University	China (PR)	Civ	Sci Research	LEO	4	2010
1043	Zhongxing 10	China Satcom	China (PR)	G	Communications	GEO	5,000	2011
1044	Zhongxing 12	China Satcom	China (PR)	G	Communications	GEO	5,500	2012
1045	Zhongxing 1A	People's Liberation Army	China (PR)	M	Communications	GEO	5,200	2011
1046	Zhongxing 20A	People's Liberation Army	China (PR)	C	Communications	GEO	2,300	2010

1046

Announced as commercial communications satellite, but believed by many to be military.

1047	Zhongxing 22A	China Satcom	China (PR)	M	Communications	GEO	2,300	2006
1048	Zhongxing 2A	People's Liberation Army	China (PR)	M/G	Communications	GEO	5,200	2012
1049	Zhongxing 9	China Satcom	China (PR)	G	Communications	GEO		2008
1050	Ziyuan 1-02C	CRESDA	China (PR)	G	Earth Observation	LEO	1,500	2011
1051	Ziyuan 3	CRESDA	China (PR)	G	Earth Observation	LEO	2,650	2012

IN SEARCH OF THE LOST FUTURE

Omar Muñoz-Cremers

It's the 21st century and culturally we wallow in retromania. How to escape? How to rediscover or redefine a true future? Omar Muñoz-Cremers analyses our predicament.

As well as being weird and wonderful cosmological phenomena, dark energy and dark matter are irresistible as metaphors. Anyone who has listened to Slayer, Underground Resistance or Scott Walker will for example happily use these terms to characterise their music. Dark energy and dark matter are also an interesting metaphor for limitations: a possible boundary to knowledge, they are the hypothetical puzzle pieces that we need in order to maintain certain paradigms; they are 'the unknown' in perhaps its purest form. We may be overcome by nostalgia when we see maps with some areas void of any detail, because here was a world in which unknown places must surely still have existed. They hold the promise of adventure, and they spark the imagination. Dark matter reinstates these unexplored areas on a cosmic scale.

This sense of nostalgia re-emerges in another form when we attempt to get to grips with culture at the beginning of the 21st century. Pop music journalist Simon Reynolds believes that our culture can be characterised by a compulsive need to look back in time. In his widely discussed book *Retromania* (2011), Reynolds exhaustively sets out contemporary culture's obsession with the past, and its repeated reappropriation of existing forms. His implication is that a lack of new ideas will result in societal stasis. It's clear that an absence of conceptual renewal is bound to have disastrous consequences, not only on an aesthetic level, but also on an ecological one. Reynolds concludes his arguments with a valiant cry: 'I still believe the future is out there!' But the reader is unlikely to believe this, given the preceding 428 pages proving the opposite. So what is it that is stopping the future? And are there still empty spaces we can point to on the map?

In the preface to his groundbreaking book *Future Shock* (1970), Alvin Toffler approvingly cites a Chinese saying: 'To prophesy is extremely difficult – especially with respect to the future'. However difficult it may be to actually observe dark matter, cosmologists can rely on the scientific method to demonstrate its existence. We have no such method at our disposal. At best it is possible to postulate an equivalent to dark matter because it is improbable that human creativity has become definitively saturated at precisely this point in history. The journey to reclaiming the future must start by identifying the obstacles along the way.

Why would an advanced technological society primarily focus on the past? It is not unthinkable that retromania will one day come to be viewed as a temporary side effect of the first phase of the Internet explosion. The fact that most of us present at that moment paid little attention to these issues should astonish no one: the arrival of the Internet was a technological leap forward with indisputable effects on society, and one that was surrounded by a futuristic aura and progressive rhetoric that left little room for the prophets of non-beneficial effects.

Nowadays one can hear a variety of critical voices, but as early as 1998 John D. Barrow used his book Impossibility: *The Limits of Science and the Science of Limits* (1998) to tentatively express some doubts about the increased level of connectivity between scientists – something that initially appeared to be exclusively beneficial. Barrow sensed a danger in the increasing uniformity that could ultimately lead to a dominance of a single paradigm in research, thereby denying smaller research groups the opportunity of developing their own ways of solving the problem at hand. Additionally, instant access to information makes chance discovery all but impossible, and the same is true of the need to pose questions in such situations – something that often sets off conversation and debate.

In two important ways, the Internet has influenced creativity and the two effects have probably magnified each other. In 1999 William Gibson wrote a passage in *All Tomorrow's Parties* that cannot be repeated often enough, because it perfectly describes the situation in which we now find ourselves:

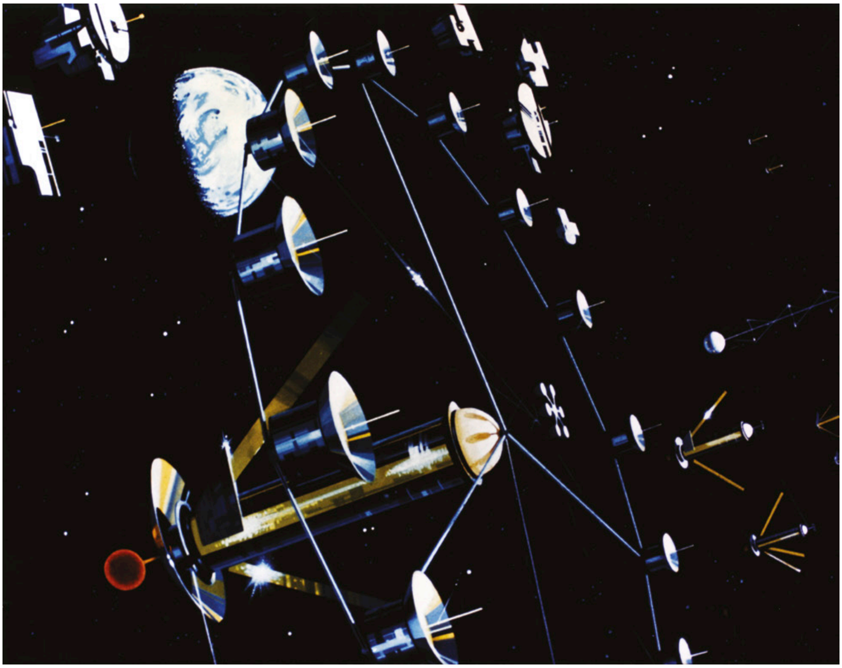
> 'Bohemias. Alternative subcultures. They were a crucial aspect of industrial civilization in the two previous centuries. They were where industrial civilization went to dream. A sort of unconscious R&D, exploring alternate societal strategies. Each one would have a dress code, characteristic forms of artistic expression, a substance or substances of choice, and a set of sexual values at odds with those of the culture at large. And they did, frequently, have locales with which they became associated. But they became extinct'.
>
> 'Extinct?'
>
> 'We started picking them before they could ripen. A certain crucial growing period was lost, as marketing evolved and the mechanism of recommodification became quicker, more rapacious. Authentic subcultures required backwaters, and time, and there are no more backwaters. They went the way of geography in general'.

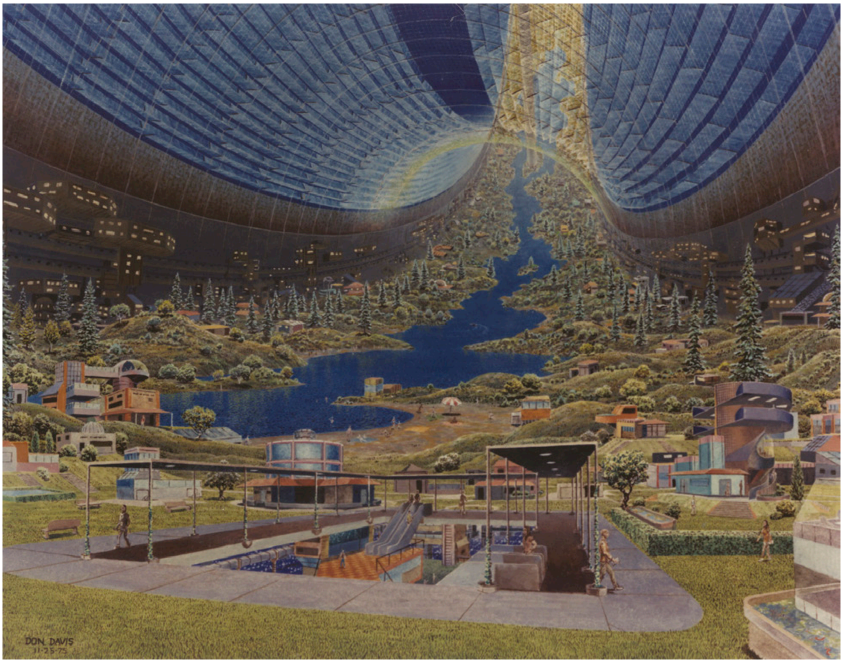
The ripening process Gibson is talking about here has since disappeared entirely through a process perhaps initially led by pioneering marketing specialists. However, social media and its associated total visibility have since rendered them superfluous.

What now exists is a network that actually works too well. These efficient information streams result in 'overcoding'. Without doubt, one component of overcoding is far more rapid discovery, not unlike a plague of locusts descending on any possible form of innovation and stripping it of its of mystery and period of development. What's more,


DON DAVIS
8:75

Cylindrical Colonies, population: over a million; endcap view with suspension bridge. Art work by Don Davis. From the three space colony summer studies conducted at NASA Ames in the 1970s.





top – Multiple two-cylinder colonies aimed towards the Sun. Art work by Don Davis.

bottom – Toroidal Colonies, population: 10,000. Art work by Don Davis.

overcoding ensures that cultural phenomena become ritualised into rigid conformances at unprecedented speeds. The final result is that any potential for renewal is subsumed by fleeting significance, sapped of its energy and then cast aside in favour of a next victim – and something is undeniably lost. Perhaps the most important loss is that of authentic enthusiasm: that pleasant sense of uncertainty one feels when discovering new territory; that moment of questioning. The way in which our lives are woven into the Internet means that there is no satisfying solution to this problem except for an extreme, off-the-grid lifestyle.

There is another way in which the Internet is directly responsible for retromania. Increased connectivity has led to objects becoming highly visible at the global level. The biggest motor driving this process is eBay. However, in its function as a digital marketplace, eBay only developed the structure for visibility and transaction; countless other websites and specialist blogs provide a second layer made up of desire and knowledge. But why is there such a fascination with objects from the past? This phenomenon recalls a marvellous trope explored by Philip K. Dick in his 1962 book *The Man in the High Castle*. In an alternative history of an apparently parallel version of the United States, antique objects become hugely valuable to collectors due to a particular quality of authenticity: an aura with a mysterious connection to an alternative reality. Naturally, the market is plagued with imitations. The aura of authenticity and the desire for artisanal durability, something that evaporates in the digital realm, must surely be an essential component of retromania.

The Internet simplifies the search, and anyway this is also a pleasant pastime. Like some online detective, one embarks on a personal adventure, searching for clues in pictures of faded labels, comparing photos, and finding serial numbers to unmask potential counterfeiters. A fascinating culture has developed around perfume, for example. It is a culture first and foremost concerned – obsessively – with authenticity. This compulsion is not only a reaction to the many counterfeits in circulation but also by cosmetics companies who have made mostly unannounced changes to their perfume formulas – connoisseurs generally prefer the original formula. The manufacture of many classic perfumes has ceased and as a result experts have come to regard some earlier periods in the history of perfume as superior to the modern day era, typified as it is by overproduction. Because the sense of smell is so highly subjective, it is difficult to codify, leading to it being surrounded by an endless discourse on issues of style, chemistry and economy. Debates of a similar nature surround articles such as watches, kits, games, cyclists' shirts. All of them are characterised by their own particular quest for authenticity.

Retromania has a technological aspect, it is fuelled by an overabundance of meaning and it possesses an almost disappointing economic dimension. If the past decade had been more prosperous, it is improbable that this backward-looking culture would have gained traction. The future has become an uncertain domain for many, and a yearning for the past is a natural human response to these conditions. At the same time, the creative industry is being battered by technological changes that are threatening to destroy revenue models. In the past, creative consumerism could rely on the drive of innovation, with product renewal forming an ethos for consumption. However, innovation has descended into a conservative repetition of all that we already know, with only the tiniest of adjustments being made to the existing working model. This compulsive repetition of previous successes is doubtless a trifling matter for a product such as washing powder, but it is tragic when it is applied to the slow wasting away of publishers due to a lack of innovation.

At this point in the argument, there is a need to propose solutions to a problem that is far too large and complex for a single individual to consider. However, there are a number of reflexes that should be avoided. The most important of these is the recurrent thought that, 'it's all been done before'. The best possible example demonstrating the redundancy of this idea is physics at the end of the nineteenth century, which was dominated by the notion that all fundamental work in this field had been completed. Apparently, certain perceptions are not possible in all eras. Something that does characterise our era, however, is the high level of collective consciousness resulting from improved schooling and faster communications. This self-confidence expresses itself through a certain degree of impatience. People feel that things should be different but feel powerless as individuals to bring about real change.

At the same time, this sense of cultural stasis is not matched by the dynamics of a contemporary world in which a number of structures and social constellations are saturated and in need of replacement. The larger the constellation – be it neoliberal capitalism or the nation state – the greater the unease about what would replace it. The fate of the large cultural industries currently adrift in heavy seas is apparently bound up with this fact, and it seems likely that they risk being displaced by the technology giants. But it's not all about the flows of finance. There is also evidence of technological saturation in design, architecture and music production. Beneath the perception that they possess infinite potential, digital tools in fact have structural imitations and restrictions. Virtual studios – with their abundant possibilities and sounds and their ease-of-use – have an iron grip on a large area of music production that is restricting the music making process. But these virtual studios do not have to be definitive models. Thatcher's famous line applying to the socio-economic domain, 'There is no alternative,' was also a bluff.

It is highly unlikely that the global economy will in the near future achieve the levels it did in the glory days of technological booms – which were based primarily on unrealistic principles and speculation. However, there is no need for this to have a negative influence on creativity; the much-vaunted Florentine model during the Renaissance is not the only workable dynamic between the economic, political and artistic spheres. Over the past 40 years, the main concentrations of creativity were in cities in decline – take New York, London, Berlin and Amsterdam, for example. Ultimately, planning and maintaining constant visibility are bigger problems for the arts than economic malaise, which instead can be a stimulus to them.

A second stimulus might be a technological leap that would create a sense of freedom, not so much as an instrument (as the PC has been for the last three decades), but purely as a source of inspiration, an opening up of possibilities. We are actually waiting for the colonisation of the cosmos. What seemed for many years of the last century to be merely a question of time is by no means certain anymore. Economic unfeasibility, health challenges and technological limitations make it increasingly unlikely that humanity will be able to leave the Earth in large numbers. We long for a life among the stars, but would never survive it. We will probably never even leave our solar system. At best, robots or some man-machine synthesis will travel in our place. One consolation is that it doesn't matter, because these ambitions are necessary to bring about technological change and the social and cultural changes with which it is associated.

And there is still the dark matter of the psyche. Since the 1960s there has been a drainage of the mind that leaves little room for alternatives. The Internet was supposed to pay out on the promise of cyberspace, but over the past decade it has been twisted towards an ordinary, plain reality: the continuous presentation of the self and glorification of the ego. There are more than enough empty areas in the atlases of this domain for pioneers to explore: daydreaming about new forms, the future rediscovered.

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WITHOUT WALLS: AN INTERVIEW WITH LEBBEUS WOODS

Geoff Manaugh

Geoff Manaugh's appreciation of the work of Lebbeus Woods, followed by an interview with the architect and artist who passed away in 2012.

Like many people, I was devastated to have learned that architect Lebbeus Woods passed away in October 2012, just as Hurricane Sandy was passing over New York City and as his very neighbourhood, Lower Manhattan, had temporarily become part of the Atlantic seabed, floodwaters pouring into nearby subway tunnels and knocking out power to nearly every building south of 34th Street, an event seemingly predicted, or perhaps forewarned, by Lebbeus's own work.

I can't pretend to have been a confidant of his, let alone a professional colleague, but Lebbeus's influence over my own interest in architecture is impossible to exaggerate and his kindness and generosity as a friend to me here in New York City was an emotionally and professionally reassuring thing to receive – to a degree that I am perhaps only now fully realising. Lebbeus mentored and taught many, many people, and I am, by every measure, the least qualified of any of them to write about his influence; but learning that Lebbeus had passed away, and under such utterly surreal circumstances, with his own city – literally, the streets all around him – flooding in the darkness as the oceans rose up, compelled me to write something for him, or about him, or because of him, or to him.

Speaking only for myself, Lebbeus is a canonical figure in the West, and I mean a West not of landed aristocrats, armies, and regal bloodlines but of travellers, heretics, outsiders, peripheral exploratory figures whose missives and maps from the edges of things always chip away at the doomed fortifications of the people who thought the world not only was ownable, but that it was theirs. Lebbeus Woods is the West. William S. Burroughs is the West. Giordano Bruno is the West. Audre Lorde is the West. William Blake is the West. For that matter, Albert Einstein, as Lebbeus would probably agree, having designed an interstellar tomb for the man, is the West. Lebbeus Woods should be on the same sorts of lists as James Joyce or John Cage, a person as culturally relevant as he was scientifically suggestive, seething with ideas applicable to nearly every discipline.

In any case, it isn't just the quality of Lebbeus's work – the incredible drawings, the elaborate models – or even the engaged intensity of his political writings, on architecture as politics pursued by other means or architecture as war, that will guarantee him a lasting, multi-disciplinary influence for generations to come. There is something much more interesting and fundamental to his work that has always attracted me, and it verges on mythology. It verges on theology, in fact.

Here, if I can be permitted a long aside, it all comes down to ground conditions – to the interruption, even the complete disappearance, of the ground plane, of firm terrestrial reference, of *terra firma*, of the Earth, of the very planet we think we stand on. Whether presented under the guise of the earthquake or of warfare or even of General Relativity, Lebbeus's work was constantly erasing the very surfaces we stood on – or, perhaps more accurately, he was always revealing that those dependable footholds we thought we had were never there to begin with. That we inhabit mobile terrain, a universe free of fixed points, devoid of gravity or centrality or even the ability to be trusted.

It is a world that can only be a World – that can only, and however temporarily, be internally coherent and hospitable – insofar as we construct something in it, something physical, linguistic, poetic, symbolic, resonant. Architectural.

Architecture, for Lebbeus, was a kind of counter-balance, a – I'm going to use the word – religious accounting for this lack of centre elsewhere, this lack of world. It was a kind of factoring of the zero, to throw out a meaningless phrase: it was the realisation that there is nothing on offer for us here, the realisation that the instant we trust something it will be shaken loose in great convulsions of seismicity, that cities will fall – to war or to hurricanes – that subways will flood, that entire continents will be unmoored, split in two, terribly and irreversibly, as something maddeningly and wildly, in every possible sense outside of human knowledge, something older and immeasurable, violently shudders and wakes up, leaps again into the foreground and throws us from its back in order to walk on impatiently and destructively without us.

Something ancient and out of view will rapidly come back into focus and destroy all the cameras we use to film it. This is the premise of Lebbeus's earthquake, Lebbeus's terrestrial event outside measured comprehensibility, Lebbeus's state of war.

What I like about Lebbeus's work is its nearly insane honesty, its straight-ahead declaration that nothing – genuinely and absolutely nothing – is here to welcome us or accept us or say yes to us. There is no solid or lasting ground to build anything on, let alone anything out there other than ourselves expecting us to build it.

Architecture is thus an act – a delirious and amazing act – of construction for no reason at all in the literal sense that architecture is outside rational calculation. That is, architecture – capital-A architecture, sure – must be seen, in this context, as something more than just supplying housing or emergency shelter; architecture becomes a nearly astronomical gesture, in the sense that architecture literally augments the planetary surface. Architecture increases (or decreases) a planet's base habitability. It adds something new to – or, rather, it complexifies – the mass and volume of the universe. It even adds time: *B* is separated from C by nothing, until you add a series of obstacles, lengthening the distance between them. That series of obstacles – that elongated and previously non-existent sequence of space-time – is architecture.

As Lebbeus himself once wrote, it is through architecture that humans realise new forms of spatial experience that would have been impossible under natural conditions – not in caves, not in forests, not even while out wandering through fog banks or deserts or into the frigid and monotonous vacuity of the Antarctic. Perhaps not even on the Earth. Architecture is a different kind of space altogether, offered, we could say, as a kind of post-terrestrial resistance against unstable ground, against the lack of a trustworthy planet. Against the lack of an inhabitable world.

Architecture, if you will, is a Wile E. Coyote moment where you look down and realise *the Universe is missing* – that you are standing on empty air – so you construct for yourself a structure or space in which you might somehow attempt survival. Architecture is more than buildings. It is a space suit. It is a counter-planet – or maybe it is the *only* planet, always and ever a terraforming of this alien location we call the Earth. Architects should radically reconstruct the outermost possibilities of the built environment – if need be, rethinking the very planet we stand on.

In any case, it's the disappearance of the ground plane – and the complicated spatial hand waving we engage in to make that disappearance make sense – that is what's so interesting for me in Lebbeus's work.

If you were to walk through an architecture school today – and I don't recommend it – you'd think that the height of invention was to make your building look like a Venus flytrap, or that mathematically efficient triangular space frames were the answer to everything, every problem of space and habitability. This is like someone really good at choosing fonts in Microsoft Word. It doesn't matter what you can do, formally, to the words in your document, if those words don't actually say anything.

Lebbeus will probably be missed for his formal inventiveness: buildings on stilts, massive seawalls, rotatable buildings that look like snowflakes. Deformed coasts anti-seismically jewelled with buildings. Tombs for Einstein falling through space.

But this would be to miss the motivating absence at the heart of all those explorations, which is that we don't yet know what the world is, what the Earth is – whether or not there even is a world or an Earth or a Universe at all – and architecture is one of the arts of discovering an answer to this. Or inventing an answer to this, even flat-out fabricating an answer to this, meaning that architecture is more mythology than science. But there's nothing wrong with that. There is, in fact, everything right with that: it is exactly why architecture will always be more heroic even than constructing buildings resistant to catastrophic rearrangements of the Earth, or throwing colossal spans across canyons and mountain gorges, or turning a hostile landscape into someone's home.

Architecture is about the lack of stability and how to address it. Architecture is about the void and how to cross it. Architecture is about the inhospitable and how to live within it.

Lebbeus Woods would have had it no other way, and – as students, writers, poets, novelists, filmmakers, or mere thinkers – neither should we.

• • •

I had the pleasure of interviewing Lebbeus a few times, to discuss specific images from his long career. Lebbeus's work remains something of an exclamation point at the end of a sentence proclaiming that the architectural imagination, freed from constraints of finance and buildability, should be uncompromising, always. His work is experimental architecture in its most powerful, and politically provocative, sense. Genres cross; fiction becomes reflection; archaeology becomes an unpredictable form of projective technology; and even the Earth itself gains an air of the non-terrestrial. Architecture and science fiction become all but one and the same.

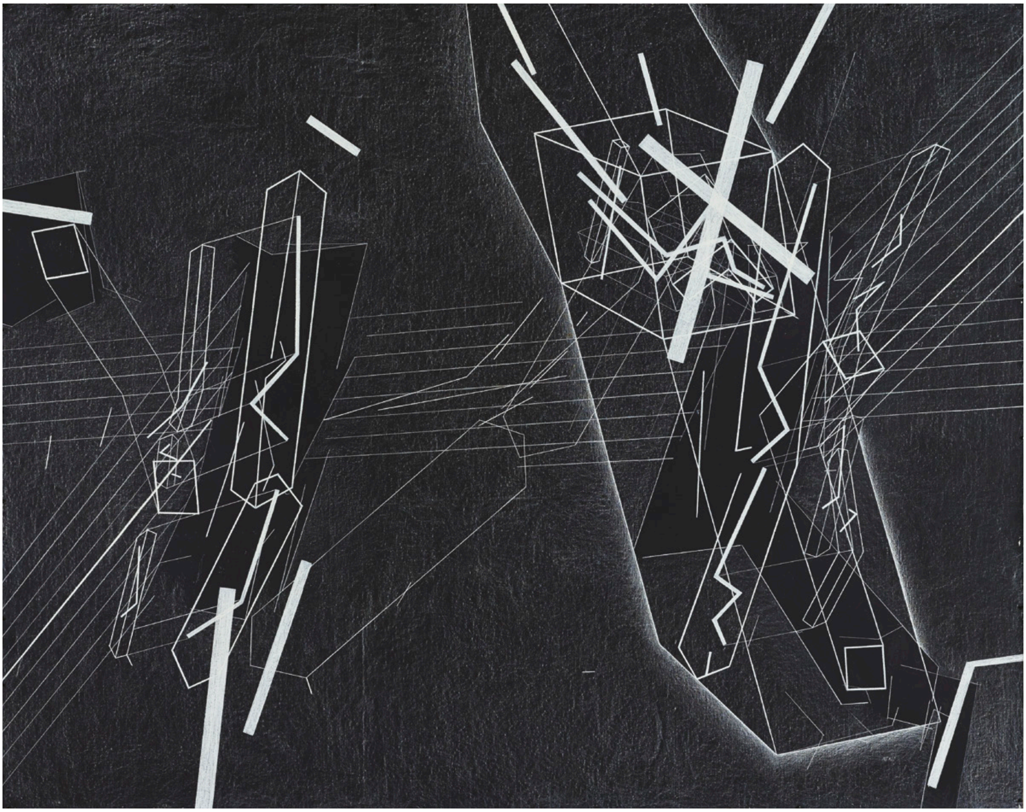
One early project by Lebbeus, in particular, has long caught my imagination. In 1980 Lebbeus proposed a tomb for Albert Einstein – the so-called Einstein Tomb – inspired by Boullée's *Cenotaph for Newton.* But Woods did not propose some paltry gravestone or mausoleum hewn out of mountain granite; it was a post-terrestrial space station, sailing through the void. *The Einstein Tomb* struck me as such an ingenious solution to an otherwise unremarkable problem – how to build a tomb for an historically titanic mathematician and physicist – that I sought Lebbeus himself out specifically to discuss the project.

In the following Q&A, originally published on *BLDGBLOG,* Lebbeus Woods and I discussed the reconstruction of urban war zones; politics, walls, and cooperative building projects in the future-perfect tense; the exposed geology of a speculative Manhattan; Arthur C. Clarke's novel *Rendezvous with Rama*; and, of course, the radically offworld architecture of Lebbeus's *Einstein Tomb.*

Lebbeus Woods, *Concentric Field*, from the series *Centricity*, 1987, graphite on paper; 58.42 cm x 60.96 cm, San Francisco Museum of Modern Art.

Lebbeus Woods, *Photon Kite*, from the series *Centricity*, 1988, graphite on paper, 60.96 cm x 55.88 cm, San Francisco Museum of Modern Art.

Lebbeus Woods, *Unified Urban Field*, from the series *Centricity* (no. 37), 1987, graphite on paper, 60.96 cm x 58.42 cm, San Francisco Museum of Modern Art. Purchase through a gift of Ned and Catherine Topham and the Accessions Committee Fund.



Lebbeus Woods, *Conflict Space 4*, 2006, crayon and acrylic on linen, 217.17 cm x 276.23 cm, San Francisco Museum of Modern Art.

Geoff Manaugh To start with, what was the origin of *Einstein Tomb*?

Lebbeus Woods To put it simply, back in 1978–80, I was looking for some philosophical grounding for architecture, other than historical references, and I was very interested in cycles, and the cyclical nature of nature and human life. I was reading – and I had read years before – people like Giambattista Vico, who was a great influence on a lot of people, including James Joyce and W.B. Yeats. I was very involved in this whole idea of the cyclical nature of life rather than the linear historical story of the Enlightenment. That's one side of the story. The other is that I was thinking of Boullée's *Cenotaph for Sir Isaac Newton*, a celebration of one of the greatest scientists of that period. I felt there should be something for Albert Einstein because his theories certainly revolutionised our view of nature and our view of the Universe. When Einstein died he wanted his body cremated and the ashes scattered – he didn't want any monuments to commemorate his life. So I was stuck with the problem of how to create a cenotaph to commemorate his thoughts and his life, yet knowing that he didn't want any such thing. How could I do it and respect his wishes? I realised that the way to do it is to build the cenotaph and then send it out into space where no one would see it. In a sense, we would know that it existed, but we wouldn't be able to visit it, or lay flowers, wreaths, or whatever, to pay homage. So, wanting to make a cenotaph and realising that it had to go into space, the idea was then very simple: one of Einstein's great contributions had to do with the speed of light. He didn't measure it and he wasn't the one who discovered it – even Newton talked about the speed of light, and there was a pretty firm idea of what the speed of light might be – but there was also this idea that outer space was filled with something called, right up until Einstein's theories, the *ether*. The ether was a substance that would transmit particles – like light particles – through space, because people couldn't imagine that things would just travel through an empty void without there being a medium. Einstein's first theory of relativity didn't challenge the idea of the ether – he just didn't mention it, and he didn't need it. It all came down to the idea of *electromagnetism*. So I thought: What if the cenotaph is somehow launched into space on a beam of light? The beam of light is fired into space, and the cenotaph is designed to ride that beam of light. Now, of course, that's a contradiction, because no material object is capable of going the speed of light – its mass would be infinite. There's also the fact that space is curved, so if we did fire a beam of light into space, we could hypothesise that, eventually, it would return to Earth. Space is not flat and infinite – it returns on itself. This is one of the consequences of Einstein's ideas. So I designed the cenotaph to follow a beam of light, and eventually it would return to Earth, in aeons of time – at least in theory. We would have the *Einstein tomb* – it would exist for us – but we couldn't see it or visit it, except in the design drawings. I felt that I'd addressed the paradox of Einstein's theories as well as his wishes not to be commemorated with a monument.

GM So it was kind of an architectural boomerang?

LW In that it returns – exactly. Of course, in many religions – particularly Hinduism – there is an idea that things will return, that there is a cycle of time. It's not just an infinite progression of time. It's also the idea of the expansion of the Universe – that there was a Big Bang, and the Universe is expanding, and it's going to go and go and go – but at some point, it's going to collapse back in on itself because of gravity. Then it will all coalesce into an infinitesimally small ball and explode again – and there'll be a new cycle. Physicists are discussing this today in a serious way – it's a theory – but the idea is that there is a finite cycle of time and space inside of which the Universe repeats. Of course, the philosopher Nietzsche wrote in his books about the idea of the eternal return – that there would be this big cycle – and of course he's borrowing that from mythology, not from science. Eventually, I abandoned that direction in my work, sometime in the mid-1980s, I'd say. I just went as far as I could go with it, and I couldn't do much more with it. In earlier years I had a philosophical concern, and actually was not at all concerned with specifics. I'd say that the philosophical element still runs throughout my work, but I've tried, now, to relate it much more to the world around me – to the world around all of us, really. I find the architecture of space programs and even much sci-fi architecture much too technological. *The Einstein Tomb* certainly doesn't look technological. But I just remembered Arthur Clarke's book, *Rendezvous with Rama*, while we were talking. In *Rendezvous with Rama*, this object is detected coming into the outer solar system. People are worried about what it is – they can't figure it out – and so they send a spaceship to intercept it. It turns out to be a cylinder: it doesn't have any sexy shape, or any aerodynamic this or that, or any technological protrusions. It's just a cylinder flying through space. The crew boards it, and they go inside, and it turns out that the cylinder is rotating along its long axis, creating an artificial field of gravity, at least on the inner surfaces. Then there's a neutral axis, the axis of rotation, where there's no gravity. That strikes me as being very interesting space architecture, because it wasn't based on a high-tech-looking thing like the Mars Lander or the Hubble Space Telescope. It was just a cylinder. Anyway, they go in and explore it, but they never really figure out what it is before they have to leave – at which point it falls into the Sun. So they don't know why it was there or what it was doing. There was obviously no one inhabiting it, but it was something like 16 miles long. Of course, Clarke was the guy who came up with the monolith in *2001: A Space Odyssey*, so you can see the relationship there.

GM Let's talk about the *Lower Manhattan* image. How did that project come about?

LW This was one of those occasions when I got a request from a magazine – which is very rare. In 1999, *Abitare* was making a special issue on New York City, and they invited a number of architects – like Steven Holl, Rafael Viñoly, and . . . oh god, I don't recall. Todd Williams and Billie Tsien. Michael Sorkin. Myself. They invited us to make some sort of comment about New York. So I wrote a piece – probably 1000 words, 800 words – and I made the drawing. I think the main thought I had, in speculating on the future of New York, was that, in the past, a lot of discussions had been about New York being the biggest, the greatest, the best – but that all had to do with the size of the city. I commented in the article about Le Corbusier's infamous remark that 'Your skyscrapers are too small'. Of course, New York dwellers thought he meant they're not tall enough – but what he was referring to was that they were too small in their ground plan. His idea of the Radiant City and the Ideal City – this was in the early 1930s – was based on very large footprints of buildings, separated by great distances, and, in between the buildings in his vision, were forests, parks, and so forth. But in New York everything was cramped together because the buildings occupied such a limited ground area. So Le Corbusier was totally misunderstood by New Yorkers, who thought, *Oh, our buildings aren't tall enough – we've got to go higher!* Of course, he wasn't interested at all in their height – more in their plan relationship. Remember, he's the guy who said, 'The plan is the generator'. So I was speculating on the future of the city, and I said, 'Well, obviously, compared to present and future cities, New York is not going to be able to compete in terms of size anymore. It used to be a large city, but now it's a small city compared to São Paulo, Mexico City, Kuala Lumpur, or almost any Asian city of any size'. So I said, 'Maybe New York can establish a new kind of scale', and the scale I was interested in was the scale of the city to the Earth, to the planet. I made the drawing as a demonstration of the fact that Manhattan exists, with its towers and skyscrapers, because it sits on a rock – on a granite base. You can put all this weight in a very small area because Manhattan sits on the Earth. Let's not forget that buildings sit *on the Earth*. I wanted to suggest that maybe lower Manhattan – not lower downtown, but lower in the sense of *below the city* – could form a new relationship with the planet. So, in the drawing, you see that the East River and the Hudson are both dammed. They're purposefully drained, as it were. The underground – *or lower Manhattan* – is revealed, and, in the drawing, there are suggestions of inhabitation in that region. So it was a romantic idea – and the drawing is very conceptual in that sense. It's peeling back the surface to see what the planetary reality is. It's not geologically correct, I'm sure, but the idea is there. There are a couple of other interesting features that I'll just mention. One is that the only bridge I show is the Brooklyn Bridge. I don't show the Brooklyn-Battery Tunnel, for instance. That's just gone. And I don't show the Manhattan Bridge or the Williamsburg Bridge, which are the other two bridges on the East River. On the Hudson side, it was interesting, because I looked carefully at the drawings – which I based on an aerial photograph of Manhattan, obviously – and the World Trade Center… something's going on there. Of course, this was in 1999, and I'm not a prophet and I don't think that I have any particular telepathic or clairvoyant abilities [laughs], but obviously the World Trade Center has been somehow diminished, and there are things floating in the Hudson next to it. I'm not sure exactly what I had in mind – it was already several years ago – except that some kind of transformation was going to happen there.

GM One of the things I like so much about your work is that youwwre-imagine cities and buildings and whole landscapes as if they've undergone some potentially catastrophic transformation – be it a war or an earthquake – but you don't respond to those transformations by designing, say, new prefab refugee shelters or more durable tents. You respond with what I'll call science fiction: a completely new order of things – a new way of organising and thinking about space. You posit something radically different from what was there before. It's exciting.

LW Well, I think that, for instance, in Sarajevo, I was trying to speculate on how the war could be turned around, into something that people could build the new Sarajevo on. It wasn't about cleaning up the mess or fixing the damage; it was more about a transformation in the society and the politics and the economics through architecture. I mean, it was a scenario I suppose, that was the kind of movie aspect to it. It was a 'what if?' There's not enough of that thinking today in relation to cities that have been faced with sudden and dramatic – even violent – transformations, either because of natural or human causes. But we need to be able to speculate, to create these scenarios, and to be useful in a discussion about the next move. No one expects these ideas to be easily implemented. It's not like a practical plan that you should run out and do. But, certainly, the new scenario gives you a chance to investigate a direction. Of course, being an architect, I'm very interested in the specifics of that direction – you know, not just a verbal description but: *This is what it might look like*. That was the approach in Sarajevo – as well as in this drawing of *Lower Manhattan*, as I called it.

GM Part of that comes from recognising architecture as a genre. In other words, architecture has the ability, rivalling literature, to imagine and propose new, alternative routes out of the present moment. So architecture isn't just buildings, it's a system of entirely re-imagining the world through new plans and scenarios.

LW Well, let me just back up and say that architecture is a multidisciplinary field, by definition. But, as a multidisciplinary field, our ideas have to be comprehensive; we can't just say: 'I've got a new type of column that I think will be great for the future of architecture'. Maybe it will be great – but it's not enough. I think architects – at least those inclined to understand the multidisciplinary nature of their field – have to visualise something that embraces all these political, economic, and social changes. As well as the technological. And the spatial. But we're living in a very odd time for the field. There's a lack of discourse about these larger issues. People are hunkered down, looking for jobs, trying to get a building. It's a low point. I don't think it will stay that way. I don't think that architects themselves will allow that. After all, it's architects who create the field of architecture; it's not society, it's not clients, it's not governments. I mean, we architects are the ones who define what the field is about, right? So if there's a dearth of that kind of thinking at the moment, it's because architects have retreated – and I'm sure a future generation is going to say: *Hey, this retreat isn't good*. We've got to imagine more broadly. We have to have a more comprehensive vision of what the future is.

GM In your own work – and I'm thinking here of the Korean DMZ project or the Israeli wall-game – this 'more comprehensive vision' of the future also involves rethinking political structures: engaging in society not just spatially, but politically. Many of the buildings that you've proposed are more than just buildings, in other words; they represent new forms of political organisation.

LW The making of buildings is a huge investment of resources. The financial, as well as material, intellectual, and emotional, resources of a whole group of people get involved in a particular building project. And any time you get a group, you're talking about politics. To me politics means one thing: How do you change your situation? What is the mechanism by which you change your life? That's politics. That's the political question. It's about negotiation, or it's about revolution, or it's about terrorism, or it's about careful step-by-step planning – all of this is political in nature. It's about how people, when they get together, agree to change their situation. As I wrote some years back, architecture is a political act, by nature. It has to do with the relationships between people and how they decide to change their conditions of living. And architecture is a prime instrument for making that change – because it has to do with building the environment they live in, and the relationships that exist in that environment.

GM There's also the incredibly interesting possibility that a building project, once complete, will actually change the society that built it. It's the idea that a building – a work of architecture – could directly catalyse a transformation, so that the society that finishes building something is not the same society that set out to build it in the first place. The building changes them.

LW I love that. I love the way you put it, and I totally agree with it. I think, you know, architecture should not just be something that follows up on events; it should be a leader of events. That's what you're saying: that, by implementing an architectural action, you actually are making a transformation in the social fabric and in the political fabric. Architecture becomes an instigator; it becomes an initiator. That, of course, is what I've always promoted – but it's the most difficult thing for people to do. Architects say: Well, it's my client, they won't let me do this. Or: I *have to do what my client wants. That's why I don't have any clients!* [laughter] It's true. But at least I can put the ideas out there and somehow it might seep through, or filter through, to another level.

GM Finally, it seems like a lot of the work you've been doing for the past few years – in Vienna, especially – has been a kind of architecture without walls. It's almost pure space. In other words, instead of walls and floors and recognisable structures, you've been producing networks and forces and tangles and clusters – an abstract space of energy and directions. Is that an accurate way of looking at your recent work – and, if so, is this a purely aesthetic exploration, or is this architecture without walls meant to symbolise or communicate a larger political message?

LW If you go back through my projects over the years, probably the least present aspect is the idea of property lines. There are certainly boundaries – spatial boundaries – because, without them, you can't create space. But the idea of fencing off, or of compartmentalising – or the capitalist ideal of private property – has been absent from my work over the last few years. I think in my more recent work, certainly, there are still boundaries. There are still edges. But they are much more porous, and the property lines... [*laughs*] are even less, should we say, defined or desired. So the more recent work – like in Vienna, as you mentioned – is harder for people to grasp. Back in the early 1990s I was confronting particular situations, and I was doing it in a kind of scenario-driven way. I made realistic-looking drawings of places – of situations – but now I've moved into a purely architectonic mode. I think people probably scratch their heads a little bit and say: *Well, what is this?* But I'm glad you grasp it – and I hope my comments clarify at least my aspirations. Probably the political implication of that is something about being open – encouraging what I call the lateral movement and not the vertical movement of politics. It's the definition of a space through a set of approximations or a set of vibrations or a set of energy fluctuations – and that has everything to do with living in the present. All of those lines are in flux. They're in movement, as we ourselves develop and change.

MONUMENTS OF SMOKE

Bitcaves

Launch of Atlas E/F X4 with a NOSS naval reconnaissance satellite. Area 576, Vandenberg Air Force Base, Florida, US between 1965 and 1974.

Reconnaissance, or spy satellites create dark voids in the sky and in the data sphere surrounding us. The infrastructure that manufactures them and the data they capture are concealed from the public gaze. However, the launches of these satellites are the brief unavoidable moments when this classified world is revealed. These 'monuments of smoke' simultaneously symbolise the paradox between the explosion of visibility and the blurring and absence of information. And unlike a satellite that captures the Earth from space, a satellite launch, as a temporary obelisk, represents reaching for the sky from the Earth.

Launch of the Swift satellite that is designed to solve the 35-year-old mystery of the origin of gamma-ray bursts, which scientists think are the birth cries of black holes. Cape Canaveral Air Force Station, Florida, US, 20 November 2004.

Launch of the ASAT(anti-satellite weapon) SM-3 missile that intercepted the reconnaissance satellite USA-193. There have been widespread speculations if the action was intended to prevent sensitive technology falling into foreign hands. Launched from *USS Lake Erie*, a US Navy guided missile cruiser, 4 January 2008.

Launch of the British Skynet military communication satellite. It was the first of two satellites to be orbited to provide Great Britain with a secure communications link between points as far apart as England and Singapore. Cape Canaveral Air Force Station Space Launch Complex 17, Florida, US, 21 November 1969.

Launch of NASA's Tracking and Data Relay Satellite-K, TDRS-K. Space Launch Complex 41 at Cape Canaveral Air Force Station, Florida, US, 30 January, 2013.

Launch of Lunar Reconnaissance Orbiter and Lunar Crater Observation and Sensing Satellite. Kennedy Space Centre at Cape Canaveral, Florida, US, 18 June 2009.

Launch of the Mars Reconnaissance Orbiter on the first Atlas V rocket used by NASA, location unknown, 12 August 2005.

The failure of the Shavit-1 launch resulted in the destruction of the $100 million Israeli Ofeq 6 spy satellite. Palmachim Air Force Base, Israel, 6 September 2004.

Launch of the Titan IVB Centaur carrying an ELINT spy satellite. The classified payload will help enhance US national security and support deployed forces. Cape Canaveral Air Force Station, Florida, US, 9 September 2003.

Launch of NASA's Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO). Vandenberg Air Force Base, California, US, 28 April 2006.

Launch of the Atlas V-Centaur rocket carrying NASA's Lunar Reconnaissance Orbiter (LRO) and Lunar Crater Observation and Sensing Satellite (LCROSS). Both satellites are the first missions in NASA's plan to return humans to the Moon and begin establishing a lunar outpost by 2020. Cape Canaveral Air Force Station, Space Launch Complex 41, Florida, US, 18 June 2009.

Launch of spy satellite. Space Launch Complex-2 at Vandenberg Air Force Base, California, US, 14 December 2006.

Launch of a spy satellite. Space Launch Complex-2 at Vandenberg Air Force Base, California, US, 14 December 2006.

~~VISIT~~ SUNNY CHERNOBYL

Andrew Blackwell

Experts agree: humans are ruining the planet. For his book *Visit Sunny Chernobyl* (2012), Andrew Blackwell set out to explore seven of the world's most degraded, contaminated environments, hell-bent on seeing the environmental apocalypse for himself. The result of his journey to the surprisingly un-dark heart of environmental darkness is a wry memoir of adventure, heartbreak, and environmental reporting – and a love letter to Earth's least-likely vacation spots. This text is an edited excerpt from Blackwell's book.

Less than two hours out from Kiev, we arrived at a checkpoint. A candy-striped bar blocked the road between two guardhouses. There were signs with a lot of exclamation points and radioactivity symbols. Nikolai – the driver – and I stepped out of the car and I gave my passport to the approaching guard. He wore a blue-gray camouflage uniform, a cap bearing the Ukrainian trident, and a little film badge dosimeter on his chest, to measure his cumulative exposure while in the area. I should have asked him where I could get one of those.

After a cursory search, we hopped back into the car. The barricade rose, Nikolai gunned the engine, and we left the checkpoint, traveling onward through the forest, down the middle of a sun-dappled road that no longer had a center line.

* * *

We had entered the Exclusion Zone. At the Chernobylinterinform administrative building, in the town of Chernobyl – nearly ten miles distant from the reactor itself – we met Dennis, my escort.

Standing at the top of the steps to the low, yellow building, Dennis matched the quasi-military vibe of the zone. He was in his mid-twenties, with an early baldness made irrelevant by a crew cut, and wore combat boots and a camouflage jacket and pants. The look was completed – and the martial spell broken – by a black sleeveless T-shirt printed with the image of a football helmet, around which swirled a cloud of English words. A pair of wraparound sunglasses hid his eyes.

'First is the briefing,' he said coolly. 'This is upstairs.' And with that he walked back into the building.

The briefing room was a long, airy space, its walls hung with photographs and maps. A wooden table surrounded by a dozen chairs dominated the center of the room. The floor was covered with an undulating adhesive liner printed to look like wood paneling. Dennis and I were alone. The summer season had yet to hit its stride. He retrieved a gigantic wooden pointer from the corner, and we approached a large topographic map on the front wall. He began diagramming our itinerary using his tree limb of a pointer, though the map was mere inches in front of us.

'We are here. Chernobyl,' he said, and tapped on the map. 'We will drive to Kolachi. Buried village.' He tapped again. 'Then to Red Forest. This is most radioactive point today.' He looked at me for emphasis. He was still wearing his sunglasses.

Turning back to the map, he continued. 'From here we will go to Pripyat. This is deserted city. Then we can approach reactor to one hundred and fifty meters.'

It was the standard itinerary, allowing visitors to inhabit their preconceptions of Chernobyl as a scene of disaster and fear – but without actually straying off the beaten path or risking contamination. This was, after all, what most people wanted. But I hadn't come all this way only to wallow in post-nuclear paranoia. I was here to enjoy the place, and this was the moment to make it happen.

'Is there any way…' How to put it? 'Is there any way we could go canoeing?'

Dennis regarded me blankly from behind his shades.

'This is not possible,' he said.

The briefing room was quiet.

'I mean, where are the really *nice* spots?'

A faint crease had developed in the dome of Dennis's head.

I pressed on, telling him that I was trying to approach this not so much as a journalist or a researcher, but as a tourist. As a *visitor*. Where, for instance, could I find a good picnic spot in the Exclusion Zone? Where did he himself go on a slow day? And if it wasn't possible in the zone, what would be the next best thing? I pointed to Strakholissya, just outside the zone, a town that I had identified while poring over a map the night before. What about that?

'Yes, this is nice place,' said Dennis. 'You can go fishing here.'

I was making progress. Fishing?

'Yes,' said Dennis, gaining speed. 'But this place is better.' He pointed to Teremtsi, a tiny spot nestled among a bunch of river islands deep inside the zone. 'This is a good place for fishing,' he said. 'I went once. Mostly I go there to collect mushrooms.'

I stared. Mushrooms, because they collect and concentrate the radionuclides in the soil, are supposed to be the last thing you should eat in the affected area. And Dennis gathered them in the heart of the Exclusion Zone.

Don't think I didn't beg. But Dennis was far too professional to chuck the official program – with all its approved paperwork, stamped and signed in duplicate for each checkpoint – just because some half-witted foreigner said pretty please. But this time, there was a moment's hesitation. 'This is, um. Not possible,' he said, getting back on script. I saw the hint of a smile on his face as he turned away from the map.

* * *

Dennis rode in front. A few hundred yards beyond the firemen's memorial, Nikolai pulled into a small gravel parking lot and jumped out of the car to buy a bottle of beer and an ice cream bar. There was a convenience store in the zone.

Within a few minutes we reached the checkpoint for the ten-kilometer zone, which encompasses the most-contaminated areas. The car barely stopped as Dennis handed a sheet of paperwork through the window to the waiting guard. He folded the rest of our permission slips and tucked them into the car's sun visor for later.

The air that streamed through the car's open windows was warm and sweet, a valentine from the verdant countryside that surrounded us. This was the famous 'dead zone.' It felt as though we were just three guys out for a pleasant afternoon drive in the country – which was more or less the truth. Dennis and Nikolai traded jokes and gossip in Russkrainian. 'We're talking about the other guide,' said Dennis. 'He's on vacation.' It seemed there were no more than a handful of Chernobylinterinform guides. It only added to the sense that I had found a traveler's dream: an entire region that – although badly contaminated – was beautiful, interesting, and as yet unmolested by hordes of other visitors.

My thoughts were interrupted by a loud electronic beep. My radiation detector had turned itself on – funny, that – and now that there was actually some radiation to detect (a still-modest 30 micros), it had begun to speak out with an annoying, electric bleat that in no way matched its smooth, iPod-from-Moscow look. There was a reason, I now realized, that this dosimeter looked like something you might take to the gym instead of to a nuclear accident site: It was designed or the anxious pockets of people who thought 30 micros were worth worrying about.

In the front seat, Dennis had produced his own detector, a brick-size box of tan plastic fronted by a metal faceplate. Little black switches and cryptic symbols in Cyrillic and Greek adorned its surface. I was jealous. It seemed there was no kind of radiation it couldn't detect, and it probably got shortwave radio too. Its design was the height of gamma chic: slightly clunky, industrially built, understatedly cryptic, and pleasingly retro. What really sold me was its beep. Unlike the fretful blurts of my PADEKC-brand meter, the beeps of this pro model were restrained, almost musical. It sounded like a cricket, vigilantly noting for the record that you were currently under the bombardment of this many beta particles, or that many gamma rays. It was a detector made for someone who accepts some radiation as a fact of daily life, and who doesn't want to lose focus by being reminded of it too loudly. Someone who is perhaps even something of a connoisseur of radiation levels. Someone like Dennis.

As we took the turnoff for Pripyat, my meter began to freak out in earnest. The reading ascended quickly from 50 micros through the 60s and the 80s, and into the low 100s. The beeping increased in pace, Guide Dennis Zabarin in Pripyat, inside Chernobyl's radioactive Exclusion Zone.

A deserted amusement park in the city of Pripyat, inside the radioactive Exclusion Zone surrounding the Chernobyl nuclear power plant.

Wildflowers and moss grow on the stairs of Pripyat's town plaza. A city of nearly 50,000 people, Pripyat was evacuated after the Chernobyl nuclear disaster, and remains empty today.


ГОТЕЛЬ ПОЛІССЯ

An abandoned kindergarten classroom in Pripyat.

in a way I could only find vaguely alarming. Nikolai glanced back at me, unconcerned, but wondering what my little meter was making such a fuss about.

We were crossing through the Red Forest. Named for the color its trees had turned when they were killed off by a particularly bad dose of contamination, the Red Forest was cut down and buried in place, becoming what must be the world's largest radioactive compost heap. Back in the briefing room, Dennis had warned me that we would experience our highest exposure while passing through this area, which had since been replanted with a grove of pine trees, themselves stunted by the radiation.

As we rounded a bend, Dennis again held his meter aloft outside the passenger window. It began chirping merrily. Meanwhile the PADEKC was going nuts. In Kiev, I had been told the upper limit on the unit was 300 microroentgens, but it now spiked from the mid-100s directly to 361. The car filled with our dosimeters' escalating beeps, which quickly coalesced into a single shrill tone that was painfully reminiscent of the flatlined heart monitor you hear on hospital TV shows.

Dennis's meter topped out at 1,300 micros, about thirty times the background radiation in New York City. He twisted around in his seat to face me. 'Yesterday it was up to 2,000,' he said. There was a hint of apology in his voice.

Over a bridge lined with rusted streetlamps and ruined guardrails, Nikolai slowed the car to weave between the potholes dotting the roadway. At the bottom of the bridge's far slope, we reached another checkpoint. Dennis adroitly snatched another leaf of paperwork out of the stack and tucked it into the waiting hand of the guard. The sign at the checkpoint read *Pripyat*.

* * *

Even more than the reactor itself, Pripyat is the centerpiece of any day trip to the Exclusion Zone. Before 1986, it was a city of nearly fifty thousand people, devoted almost entirely to running the four nuclear reactors that sat just down the road and to building the additional reactors that were to be added to the complex. At the time of the accident, Reactors Nos. 5 and 6 were nearing completion, and a further six reactors were planned, making the neighborhood a one-stop shop for the area's nuclear energy needs.

It didn't take long after Reactor No. 4 exploded and caught fire for the residents of Pripyat to realize there had been an accident. Anyone looking south from the upper stories of Pripyat's tall apartment buildings could have seen smoke belching from the maw of the destroyed reactor building some two kilometers distant. What they didn't know was that it was no ordinary fire; it was the reactor's core that had blown, creating a sky-high plume of radioactive steam, smoke, and nuclear fuel particles, right in Pripyat's backyard.

The city was bathed in radiation, but the residents remained uninformed. They continued about their business for more than a day, while the government scrambled to contain the accident. Finally, at noon on April 27, nearly a day and a half after the explosion, the authorities announced their decision to evacuate the city. When at last the order was given, it took only hours for this city of fifty thousand people to become a ghost town. The evacuation was broadened over the following days to include more than a hundred thousand people. Ultimately, more than three hundred thousand were displaced.

Pripyat sat empty. In the months and years following the evacuation, it was looted and vandalized by people obviously unconcerned by the radioactive nature of their spoils, whether televisions for their own use or metal items to be sold as scrap. The evacuation and the looting turned Pripyat into what it is today: the world's most genuinely post-apocalyptic city.

In spite of what you might have seen in the movies, though, things can actually be pretty nice after an apocalypse – if a bit scarce in terms of human beings. The road that led us into Pripyat from the south was lined with bushes speckled with small white blossoms, the air thick with the smell of flowers. The vista opened up as we reached the center of town, allowing a view of the buildings around us. Dennis and I clambered out in the middle of an intersection, and Nikolai motored off down a side road to find a nice spot to sit and drink the beer he'd bought earlier.

The day was hot and sunny. The ghostly city surrounded us, the buildings of downtown looming up from behind scattered poplar trees. Behind us rose a ten-story apartment block. Its pink and white plaster facade was falling off in patches, revealing the rough brickwork of the walls underneath. More apartment blocks stood along the road to the left, some of them crowned with large, Soviet hammer-and-sickle insignia.

We walked toward the town plaza, following a path that had once been a sidewalk but was now a buckling concrete track invaded by weeds and grass. Dennis lit a cigarette and looked up as he took a long drag. A gentle breeze pushed a herd of little clouds across the sky. Birds flitted by.

The plaza was bordered on three sides by large buildings. To the right, a defunct neon sign announced the Hotel Polissia, seven stories of square, gaping windows. From where we stood, more than twenty years of looting and abandonment had not significantly worsened the stark, unforgiving aspect of the hotel's architecture. A few hardy shrubs even peeked from among the freestanding letters of the roof sign. It's amazing where things will grow when people stop all their weeding.

To our left was a blocky building with a sign reading *pectopah*. Using my nascent Cyrillic, I decoded this as restaurant. I pointed to a low-slung gallery that jutted from its side.

'What was there?'

Dennis looked up and removed the cigarette from his mouth.

'Shops.'

The plaza where we stood was gradually surrendering itself to shrubs and moss. Vegetation spilled over its borders and crept along its seams. A set of low, crumbling stairs led up from the plaza's lower level, purple wildflowers and a few tree saplings poking out from the cracks.

'Don't step on the moss,' Dennis ordered as we walked up the mossy stairs from the mossy lower level to the mossy upper level.

'Why's that?' I asked, and hoped he hadn't seen the contorted tap dance of my reaction.

'The moss... *concentrates* the radiation,' he said, and tossed his cigarette butt on the ground. The same could have been said for the mushrooms he had freely admitted to gathering in the zone, but I didn't bother to point it out.

Dennis wandered away along the side of the plaza, his detector in a lazy warble. I lingered in front of the gutted *pectopah*. There was nothing left but a shell of cracked concrete and twisted metal. I tried to imagine the plaza before the accident, when it had been the center of a living city. A place to meet a friend after work, maybe. Somewhere to have a cup of bad coffee. What was it like to have your entire town evacuated in three hours? To lose not only your house or apartment but also your workplace, your friends, your entire environment? I tried to imagine the terror of that day.

But it was difficult, in the peace that reigned over present-day Pripyat. I closed my eyes and felt the sun on my face. The trees and grass rustled in the wind. Insects buzzed past on their way to somewhere else. I heard the easy cacophony of the birds. And as Dennis made his way down the plaza, the chirping of his dosimeter dissolved into the birdsong, becoming just another note in nature's symphony.

* * *

By the time we reached the reactor complex, some ways south of Pripyat, the day had turned itself inside out. We had heard thunder rumbling in the southeast, and now a thick lid of clouds had slid over the sky and heavy raindrops were striking the car's metal roof.

Our surroundings were similarly changed, with forbidding expanses of concrete and clusters of squat buildings – the infrastructure for maintaining the reactor building. Through the car's streaming windshield, I saw a dented metal gate blocking our way and a pair of concrete walls haloed with messy helixes of barbed wire.

On the other side of it all, attended by several spindly yellow construction cranes, was the Shelter Object. I was struck by its great size. The interlocked metal walls rose in a colossal vault, battleship gray streaked with rust, supported on one side by tall, thin buttresses and on another by the giant, blocky steps of the so-called Cascade Wall. Pipes and bits of scaffolding clung to its battlements, whose flat surfaces were interrupted by a grid of massive metal studs. Catwalks traced the edges of its multiple roofs, and a series of tall, shadowed alcoves notched the top of the north wall, like portals from which giant archers might rain arrows down on the countryside.

I had envisioned this moment differently. Visiting the reactor building, I had assumed, would not be fundamentally different from visiting the Eiffel Tower or the Taj Mahal. But those thoughts vanished under the growing thunderstorm. Instead, I felt an unexpected, visceral repulsion. The *thing*. It was obscene. A monument to brutality, a madman's castle under siege from within.

And unlike other buildings or monuments, it lived. It radiated danger and fear, had warped the land for miles around, creating its own environment, breathing the Exclusion Zone to life.

This text is an excerpt from *Visit Sunny Chernobyl: And Other Adventures in the World's Most Polluted Places* (New York: Rodale, 2012).

IN THE SHADOW OF ITS OWN BRILLIANT LIGHT

Interview with Saskia Sassen
Willem van Weelden

At Sonic Acts 2013 the renowned sociologist Saskia Sassen delivered a passionate lecture showing many dark sides of globalisation. This lecture, entitled *Before Method: Analytic Tactics*, also demonstrated her way of working and analysing a world in which the meaning of concepts such as family, nation, government, city or neighbourhood have become radically unstable. The Dutch independent researcher Willem van Weelden interviewed her afterwards, and corresponded with her through e-mail.

'Everything that appears automatically falls under the suspicion that in its very act of appearance, it also hides something else behind it'.

Boris Groys, *Under Suspicion: A Phenomenology of Media* (2012)

Willem van Weelden From your first book *The Mobility of Labour and Capital* (1988), in which you demonstrated that foreign investments in less-developed countries in fact raise the likelihood of emigration, you have set out to demolish or at least cut through established 'truths based on a counterintuitive method and a focus on the unexpected'. To be able to arrive at such corrective conclusions, it must take you years to harvest the enormous amounts of information, assembled from all over the world, for each new project and publication. Could we therefore speak in this regard of a 'Sassen info-machine', an information-filtering machine that not only cuts through established 'truths', but moreover through these enormous amounts of data and info? Could you explain the daily practice of your information refinery work? Is the filter that you apply to refine this information ultimately scientifically driven or is it increasingly political?

Saskia Sassen Your description is very funny. You are capturing something about my work process. It is a sort of machinery that moves through vast amounts of data and their interpretations with my sights set on particular objects... not quite of desire, but still, objects. I would add, that on some level, throughout this process of tracking I'm on the alert to pick up a connection, possibilities – even when people are talking about an unrelated subject. A kind of mental map develops over the years, an architecture that has a logic, so that when I read or hear or discover something, I can place it in the corresponding layer or box in the conceptual architecture. This conceptual architecture also allows me to know what I still need. In retrospect I have come to see that my starting point is the instability of core meanings and core categories through which we capture complex conditions. I think that in the 1980s and into the 1990s, when our current global era begins, many key meanings (for instance, the meaning of the national economy, the meaning of city, the meaning of family) started becoming unstable due to the new global forces. There was a time in the post World War II decades, when, whether you were in Europe, South America or North America, you had a good sense of what a national economy was, or the family, your neighbourhood. In Sweden the government is still doing a lot for its citizens, but in the Netherlands, which always has had a reputation as a strong welfare state, the government is now doing far less now than most people outside the Netherlands are aware of. There used to be a sense of what the national government did – or didn't do. It is not that all this is completely gone now, but the meanings are unstable. We need to actually find out what the government in each specific country is doing for its citizens. So I need to actively destabilise stable meanings in order to understand particular types of questions not contained in the dominant categories of a period or a field of scholarship. This is a research and interpretation practice we need, especially at a time of rapid transformations. States, economies, families, they are all still around, but their meaning is different from what it was in the 1950s and 1960s. What social scientists typically do is to say 'it has changed', and then measure the differences. But whatever those findings, they are still represented by that inherited category and this one may no longer be as useful as it once was. Thus today we say there is more inequality – I ask: at what point is the concept 'inequality' insufficient to capture what is actually going on: expulsions from life spaces is what is going on for more and more people. Another step that is part of my research practice is that, 'to study the x, we need to focus on the non-x as well'. Thus to an example from my first book *The Mobility of Labour and Capital*: to understand migration it is not enough to have detailed knowledge about the migrants themselves; detailed knowledge about the larger political economy was also needed. A third step in my research strategy is that a powerful explanation is to be taken seriously, because it keeps me from seeing a whole range of other aspects. It's powerful precisely because it distils a few major aspects and gets rid of the rest, otherwise it wouldn't be an explanation – let alone a powerful explanation. So my move is then to ask: 'what does it keep me from seeing precisely because it is so powerful?' My research practice is to then discover what is hidden in the shadow of a powerful explanation, in the shadow of its own brilliant light. I think of these as 'analytic tactics' – a practice that precedes method, a sort of space where I allow myself to explore outside the box of method. As I argued in my lecture 'Before Method: Analytic Tactics' at the Sonic Acts symposium this year.

WW As a sociologist of globalisation and international human migration you have shown a dedication to and an engagement with themes that are politically charged, like your concern with inequality and dispossession, the fate of women, or what you have called 'the emerging logics of expulsion' – the growing development of expulsions of large sectors of society. In your description and use of the term it becomes a many-headed monster that

In 'Before Method: Analytic Tactics' Sassen stressed the (necessary) inconclusiveness of her lecture, and argued for the necessity of bypassing and critiquing the traditional methods applied in social science that are based on the reiteration of fixed categories of research that may produce 'clear' outcomes, but in fact obscure the complexity of the social realities at hand. In that respect she referred to John Law's book *After Method: Mess in Social Science Research* (2004), in which Law argues for a rethinking of method. As for him: 'Method is not a more or less successful set of procedures of reporting on a given reality. Rather it is performative. It helps to produce realities'.[1] This conceptual stance implies that research can never exclude nor ignore the political implications of its findings and results, because of its performative nature. It actually creates what post-structuralism has identified as 'truth effects'. Methodological critique already has a standing tradition that includes publications by Ludwik Fleck (1935), Thomas Kuhn (1962), Paul Feyerabend (1975), Bruno Latour and Steve Woolgar (1979), but it seems to have reached a new culmination point, considering the epochal transformations and complexities due to the ever increasing process of globalisation that inherently defies traditional methodological approaches. From her first publication on, Sassen's work has shown an 'aberrant' relationship towards traditional sociological methods as she tried to ground her work about globalisation in an active avoidance of what she has later called 'the endogeneity trap'.[2] She avoids types of sociological research that only provide mere descriptions of the process of globalisation based on ossified categories of research. Those descriptions remain trapped in their own poor methodological confines, and these are incapable of showing or laying bare the systemics that originate, organise and produce the process of globalisation. With her idiosyncratic take on method, Sassen takes on the challenge of explaining rather than merely describing. For Sassen, explaining means acknowledging the political effect and ramifications of the research.

1. Law, 2004, p. 143.
2. Sassen, 2006.

operates on various aggregated levels, as they have to be understood as demonstrations of a deeper systemic transformation, an overarching dynamic that points to a new phase of globalisation. In this new phase of what you call 'advanced capitalism', you seem to take sides with the so-called losers of these recent developments.[3] Is this siding with the losers inspired by your assumption that these topics are obscured and actively made invisible to the global eye by the gross categories that determine the more general discourses on global governance and ignore the historic change in how human beings are being 'valued' in these issues?

SS Yes, in many ways you're right. But it is partly a representational question. I am engaging dominant narratives on for example their insistence on what it means to develop a 'proper' economic policy. Privatisation, cutting social benefits, deregulating finance, et cetera, all these presumptions that this is the only way to have economic growth and a sound economy for all. Now the evidence is in: it hasn't worked for more and more people, places, and even entire economic sectors. Yet the dominant story is still that this is the only way. Angela Merkel believes it, Obama does, but also the average middle-class person who has until now benefited from the capitalist liberal state and cannot accept nor believe that the middle class is no longer the darling of capitalism that it was in the 'Keynesian' phase. So I have to go digging in the penumbra that these powerful dominant ideas generate. It's not simply attacking those ideas and 'protecting' the weak, it's laying out a more objective set of issues. I try to be non-ideological and just let the data do the work – data that I dig out, covered in mud, and hence not always immediately recognisable to the conventional social scientist as data. It was far more difficult to do this and persuade others in the 1980s than today. I was already arguing then that we were entering an era of growing inequality. But most social scientists at that time declared, found and argued that everybody was doing better and had more money. My argument at the time, especially developed in *The Global City* (1991) was that a significant share (about 20%) of the middle class, especially in major cities, was becoming richer than they ever thought they would. But that left 80% of the people out of the picture. And these were to a large extent invisible, except for the homeless. The modest middle classes and the working classes were losing ground, they lived in the same modest houses they had managed to buy or rent in the pre-global era: but behind those same old walls they were becoming poorer, and eventually by the late 2000s real poverty arrived for them and for their children.

WW The text 'A Savage Sorting of Winners and Losers, Contemporary Versions of Primitive Accumulation' in *Globalizations* has at its base your exploration of the possibility that capitalism today is undergoing the systemic equivalent to Marx's notion of 'primitive accumulation', predicated on the destruction of more traditional forms of capitalism. The Marxian notion of primitive accumulation states that before money can be changed into capital, an original accumulation must take place, like resource extraction, conquest and the plundering of land, and enslavement. The accumulation of low cost land and resources are a crucial element in this development, think, for instance, of China's activities in Africa. Could you sketch out the scale, largely invisible to the public eye, at which this is happening,

3. See Sassen, 2010, vol. 7, 1 & 2, pp. 23–50.

and what it effects are, for example the survival strategies and circuits they induce, like migration streams and people trafficking?

SS I would say at least two aspects are in play: one is indeed the massive land grabs. Over 220 million hectares of land have been bought by foreign governments and foreign firms since 2006 (the data go up to 2011, and the trend has continued). The other is the financialising of everything: of used car loans, of student loans, now of medical bills. It becomes the mechanism through which primitive accumulation takes place in our complex, multi-sector economies. This is one of the meanings of the title of my *Expulsions* book: the extraordinary growth in complexity that produces, in the end, elementary brutalities. These complex processes geared towards maximising profit and advantage tend to take place in the intermediary sectors of the economy: financial services is one of them; others are increasingly complex legal, accounting, insurance, and logistic services. Every transaction now requires more and more lawyers, accountants, advisors, consultants. These sectors operate between the actual economic sectors in play (manufacturing, transport, health services, mining). Because they are intermediaries, they do not go under. They make their profits even if the firms they advise suffer a loss or go under. This began to take off with the 'Mergers and Acquisitions' boom of the 1980s, when many of the firms that were merged went broke, but the lawyers and financiers made vast profits. It is clearly an abusive outcome that distorts the actual economy. Or take outsourcing: it means complex logistics, huge cargo ships, dealing with different economic, accounting and employment cultures overseas – and all of that for what?! To avoid environmental and labour laws, to extract more labour from workers every single day, all of it translating in just a few dollars of added profits every work day for each worker. There are many, many more examples of how the growing complexity of our economies, especially through the addition of intermediary sectors, produces elementary brutalities.

WW Information technologies and electronic communication have not only brought us the dubious wonders of a global financial market but also a violent, predatory crisis, referred to by many as 'the crisis of crises'.[4] To them this financial crisis exemplifies the inner contradiction of the project of globalisation and a possible historical watershed moment for its development. This contradiction is also a recurrent key theme in your work on globalisation, for instance concerning the nation state *vis a vis* the global realities. But is this financial crisis in your studies on cities in a world economy the focal point, the lens through which you look at the current developments in globalisation? Or are other perspectives more crucial and critical to arrive at a better understanding of that process? Has your view changed since your book *The Global City*, which started with an analysis of global markets, trading patterns, and global circuits of transmitting standards?

SS Well, yes and no. I still think many of these processes matter, not only finance. But finance is the steam engine of our epoch: a critical factor, present everywhere directly and indirectly. This is also why I argue that finance is not about money, unlike the traditional banking sector.

4. See Christian Marazzi, *The Violence of Financial Capitalism,* New York: Semiotext(e), Intervention Series #2, 2010.

Stills from the documentary film by Alexis Marant, *Planète à vendre / Planet for Sale: The New World Agricultural Order*, 2011.

top – Ethiopian villagers.
bottom – Wheat fields in the Saudi desert.

It is a capability, which very easily becomes destructive. Finance lives off the financialising of other sectors: it needs to invade them. That is what financialising means. That is its power and its capacity to destroy not only firms and households, but also entire economies, as happened in Greece. The steam engine was everywhere, but it functioned as an enabler (and a polluter!) whereas finance sucks value out of every sector it financialises. The value of finance since the crisis in 2007–8 has actually increased, after a sharp fall. It now stands at over a quadrillion, that is more than a trillion, whereas global GDP,[5] which stood at 54 trillion in 2007, fell to about 46 trillion. In other words, the 'real' economy (a term I don't like very much, but it is a familiar way of putting it) as measured by GDP actually registered the costs and the pain of the crisis. Finance did for a very little while, but by 2010, with government bailouts and even more sophisticated methods to invade other sectors, it began to rise sharply again, growing from US$630 trillion (as measured by outstanding derivatives – remember, finance is not about money!) to over a quadrillion by 2013. This is a monstrous inversion of how it should have been: finance should have fallen dramatically, which it would have if it were traditional banking, which is about money. A critical aspect in my work on the global city is that I conceive of it as a space where today's increasingly private and elusive, partly electronic power actually hits the ground and becomes material: office buildings, luxury residences, all kinds of services and workers, from professionals to cleaners. Because it becomes material it can be engaged with by those who lack power. In that sense the global city is a frontier space, where actors from different worlds have an encounter for which there are no established rules of engagement. In this case, to simplify, it would be the high-level global professionals and the average modest-income city resident. But also the encounter between global capital and the modest small enterprises (shops, restaurants, urban factories) that constitute the actual urban economy. So the global city is also the space where those without power can engage the most powerful forms of power and thereby make history. Powerlessness can become complex in the space of the global city, in contrast to the space of the plantation.

WW As you have pointed out globalisation not only signifies a worldwide network of exchange but also new forms of hierarchies and a redefinition of power structures, even new geographies of power, giving rise to deep transformations in both physical and immaterial information domains. In *Territory, Authority, Rights (TAR)* (2006) you already paid attention to the limits of derivatives trading that is becoming evident. There is increasing recognition in the financial world that fundamental mathematical and statistical assumptions built into the risk models they applied do not adequately represent the dynamics of the derivatives trading markets. *TAR* was published in 2006, years before the crisis. But apart from its prophetic qualities your point indicates a gap between the academic world and the trading practices. Were you indicating that it must be seen in the light of a general erosion of academic knowledge in business and governance and must it not be interpreted as a trend of de-intellectualisation in decision-making processes? And if so, what is your current view on this issue?

5 GDP = Gross Domestic Product: The total market value of all final goods and services in a country in a given year, equal to total consumer, investment, and government spending, plus the value of exports minus the value of imports.

top – Protests in Tahrir Square on 8 April 2011.
bottom – Immigrants on the deck of *S.S. Amerika*.

SS: Yes and no… Yes, because academic economics has become demonstrably inadequate to a) guide financial investments, and b) explain how today's financial markets and private trading networks actually work. In chapter 5 and 7 of *TAR* I was just establishing what I found to be a more correct version. I added elements to the existing analysis: for instance, a lot of the analysis by academics at the time overlooked the fact that when a firm enters the financial markets – when it launches an algorithm into the electronic market networks – all kinds of network interactions are set in motion. I wrote in *TAR* of a network effect that could alter the predictions of even the best firm. And this cannot be fully controlled. I don't think that advanced finance today can be regulated: the regulators will always be behind financial innovations and countermeasures. What governments can do is make laws that assert that finance cannot invade core economic sectors. Finally, finance is a profoundly speculative activity – financiers can, and perhaps have to be gamblers, unlike traditional bankers who simply sold money they had. Third, there has been a lot of corruption and criminality. But the system is so complex that governments simply cannot track the data and think they can build a solid case. In short, much of the top Wall Street financial leaders should be in jail.

WW Starting with the farce of the Iraqi wars, with delusional information being accepted by world leaders as policy-shaping givens, and the corrective work of WikiLeaks following soon afterwards, it seems that the genie could be out of the bottle: critical information that was supposed to be secret in fact happened to leak. I don't want to discuss the specifics of the WikiLeaks case with you, but do you feel that nation state control has increased to safeguard critical information and to impose restrictive measures to disable free access to public information as countermeasures to the resistance and effectiveness offered by initiatives like Wikileaks, Anonymous, and even cybercrimes allegedly committed by the Chinese authorities? Has your work become increasingly more difficult in terms of gaining free access to desired info or data?

SS It seems almost that as 'democratic' governments lost some of their power, they still had to control their countries. This loss has now been compensated and distorted by a growing concentration of unaccountable, privatised power in the executive branch of government. I see two trends within the executive branch of government. One of these I develop in great detail in the fourth chapter of *TAR*: it is the growing trend in the executive branch to privatise its power and make it unaccountable. This is very strong in the US, but is also evident in the major European countries. By the executive branch I mean not just the executive office (whether prime minister or president) but also the key agencies that work with the executive. Their power has grown enormously with globalisation: central banks, ministries of finance, commerce, and if war is involved, as in the US, the Departments of State, of Foreign Affairs, and the military, the Pentagon. In my reading of the growth of the power of the executive branch I differ from most of the globalisation literature that argues that 'the' state loses power in the global era. 'The' state is too general! Much of the state loses power, but not the executive branch. The second trend is the massive growth in the surveillance of citizens. And I don't mean traffic speed surveillance. There is a rapidly expanding system over the last decade that connects the executive branches of governments of several countries (US, UK, Germany, the Netherlands). In the US we know there are ten thousand buildings running surveillance 24 hours a day every day, every month, non-stop. One estimate has it that, for instance, every day over two billion e-mails sent or received by US residents are tracked by a cohort of approximately 854,000 people with top-level clearance, and a vast array of non-top clearance staff, all of it without any formal authorisation to do so. *The Washington Post* has undertaken a detailed study of the domestic surveillance programme that the Bush administration installed shortly after the 9-11 attacks and which still continues today, which allows the National Security Agency to proceed with this surveillance – amazing data! The basic logic of such a surveillance system is that we are all being surveilled. That is to say, the logic of the system is that as a first step we must all be considered suspect in order to ensure our safety. Who, then, have we the citizens become, or been turned into? Are we the new colonials? I developed some of this recently with links to data in an *Al Jazeera* piece 'Surveillance over here, drones over there'.[6] The source of this excess of executive power is a foundational distortion at the heart of the liberal state. The liberal state was never meant to bring equality of opportunity and full recognition of all members of the polity. Inequality was at its core since it's beginning. Even the so-called Keynesian period, which engendered a prosperous working class and an expanding modest middle class throughout much of the West, was but a partial democratising of the economy that left the executive branch with considerable power. One basic element in this increasing power of the executive branch of government in our global age is that it plays a key role in implementing the new rules that a global economy and global capital market needs. Thus the IMF, the WTO, and dozens of other regulations-imposing institutions only deal with the executive branch of the governments they have to deal with, which is almost all in the world. Going through legislatures would have meant bringing far too much into the public eye, and subjecting it to debate in the legislature. Most residents and national firms did not necessarily like privatisation, deregulation, and open borders for global capital. So keeping it confined to the executive branch was much better. In playing the game, the executive branch gained a privatised, secretive power, but at the cost of ensuring that global firms and global capital markets got what they wanted. Thus the big-bank bailout after the 2008 crisis in most of our countries is not so much a return of the strong nationalist state, as some would have it, but rather the executive branch using national law and national taxpayers' money to rescue a global financial system. In the 2000s, just about all liberal democracies were in sharp decline, with growing inequality, weakened unions, impoverishment of the modest middle classes, and an enormous seizure of the country's profits by the top layer of firms and households. This is all captured in a couple of numbers found in the US census: In 1979, the top 1% of earners in New York City received 12% of all the compensation to workers in the city, a reasonable level of inequality in a complex economy such as is NYC. (This share excludes non-compensation sources of wealth, such as capital gains, inheritance). In 2009, the top 1% received 44 percent – a level of inequality that cannot be good for the city's economy. At its most extreme, this combination of massive surveillance and savage inequality may be signalling a new phase in the long history of liberal democracies, one where the executive branch gains power partly through its increasingly international activities. Over the last twenty years and more, this incipient internationalism has been deployed in

6. See Sassen, 2006.

support of developing a global economy and fighting the War on Terror.This is a kind of internationalism. It's a pity that it's being deployed for this. It is possible that these new international capabilities of the executive branch might be reoriented to more worthy aims: climate change, global hunger, global poverty and many others requiring new types of internationalism. But it will take some major occupying of the executive branch of government!

WW Around 2000 you published a lot on the rise of the Internet and electronic communication. One of the articles I remember from those years focused on two distinct cases: one on electronic networks in finance and the other on electronic activist networks. More recently you have written about the Arab Spring, the *piquetieros* in Latin America, the daily protests in China, or Tel Aviv, and the Occupy movement. You state that the street – in contrast to the European piazza or boulevard as the ritualised space for public activity – has gained a new dimension, a dimension of literally making the social and the political happen. Is it fair to say that these developments have opened a new conceptual domain to your research, in the sense that they introduce the notion of presence of the powerlessness? Could you describe your thoughts on the issue of public empowerment after having seen the rather grim aftermath of the recent uprisings in the Arab world?

SS The concept of the global street seeks to capture a space where those who do not have access to the formal instruments for making history (such as the invasion of Iraq), or control over a government, or a politics (such as the neo-liberalisation of democracies), get to make a history, a politics. In this process they also become present to each other, they make presence – the powerless becoming present. I have been using the notion of 'making presence' for a very long time. Becoming present, visible, to each other can alter the character of powerlessness. I make a distinction between different types of powerlessness. Powerlessness is not simply an absolute condition that can be flattened into one sole meaning: the absence of power. I want to understand under what conditions powerlessness can become complex, even if the powerless do not become empowered. Many of the protest movements we've seen in North Africa and the Middle East are a case in point: these protesters might not have gained power, they are still powerless, but they are making a history and a politics. The notion that powerlessness can become complex can be used to characterise a condition that is not quite empowerment. Powerlessness can be complex even if there is no empowerment. Seeing it this way adds significance and importance to so many of these uprisings that are not necessarily giving the participants power. But they are making history.

Occupying is not the same as demonstrating. Many of the protests – Tahrir Square, Los Indignados, Occupy Wall Street, and others – made it clear that occupying makes novel territory, and thereby a bit of history, using what was previously considered merely ground. Territory is itself a strategic vector in all these very diverse processes of occupation. In the sense in which I am using it, territory is a complex condition with embedded logics of power and of claim-making, something that it takes work to create, and which cannot be reduced merely to the elementary facticity of ground or land.

To occupy is to remake, even if temporarily, territory's embedded and often deeply undemocratic logics of power, and to redefine the role of citizens, mostly weakened and fatigued after decades of growing inequality and injustice. Indeed, the occupations have revealed to what extent the reality of territory goes beyond its dominant meaning in the twentieth century, when the term was flattened to denote national sovereign territory.

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EXTRA-STATECRAFT

Keller Easterling

The free economic zone has become a contagious world city paradigm. While in the 1960s there were a mere handful of such zones around the world, today there are thousands, with some spanning hectares and some square kilometres. Operating under authorities independent of the domestic laws of its host country, the zone provides special infrastructures and a set of business incentives such as tax exemptions, foreign ownership of property, streamlined customs, cheap labour and deregulation of labour or environmental provisions. At Sonic Acts 2013 architect and writer Keller Easterling delivered a talk on these zones of 'extrastatecraft'.

The promotional videos invariably follow the same template. A zoom from outer space locates a point on the globe, and graphics indicating flight times demonstrate that it is located at the midpoint of the Earth. A deep movie-trailer voice and stirring heroic music accompanies the swoop through cartoon skylines, resorts, suburbs and sun flares. The videos describe the world's most popular and contagious world city paradigm – the formula that generates Shenzhens and Dubais all around the world. It is a dominant urban software or template called the free zone. So contagious is this spatial technology that every country in the world wants its own free zone skyline. Some versions of the zone are found in King Abdullah Economic City in Saudi Arabia, New Songdo City in South Korea, Manaus Free Zone in Brazil, Cyberjaya in Malaysia, HITEC City in Hyderabad, Konza Technology City in Kenya, Ebene Cybercity in Mauritius, and everywhere in between. While in the 1960s there were a handful of zones in the world, today there are thousands, with some measured in hectares and some in square kilometres. Zones in over 130 countries handle a third of the world's trade.

Operating under authorities independent of the domestic laws of its host country, the zone typically provides special infrastructures and a set of business incentives such as tax exemptions, foreign ownership of property, streamlined customs, cheap labour and deregulation of labour or environmental laws. The site of head-quartering and tax sheltering for most global power players, the zone has become a self-perpetuating agent in the growth of extrastate territory. It has also become an essential partner for the state as it attempts to navigate and profit from the world's shadow economies. Yet far from overwhelming state power, the state and its new partners often strengthen each other by serving as the others proxy or camouflage. They pursue an extrastatecraft – a portmanteau that means both outside of and in addition to statecraft.

Even as the world scrambles to adopt this form, no one really knows why we use it. It is a relatively dumb recipe for enclave development and a poor economic instrument, but the world has become addicted to its incentivised urbanism.

With ancient roots in pirate enclaves and free ports like Genoa or Hamburg, the zone evolved from an early twentieth-century warehouse compound for storing custom-free trade. In 1934, emulating freeport laws of the late 19th century in Hamburg and elsewhere, the United States established Foreign Trade Zone status for port and warehousing areas related to trade. At mid-century, the United Nations Industrial Development Organization (UNIDO) promoted a form of the zone that merged warehousing with manufacturing in export processing zones, or EPZs. Using scripts about nation-building and free trade, the UN and The World Bank promoted the EPZ as one means by which developing countries might jump-start their economies, enter the global marketplace and attract foreign investment. By the 1970s, both agencies were concerned about the independent authority of the zone and its tendency to produce enclaves. If anything other than a temporary experiment, they judged it to be a sub-optimal economic instrument. Yet the EPZ spread widely during the 1970s even as it also spread new waves of labour exploitation.

After China adopted the form as a market experiment in the late 1970s, the numbers of zones began to grow exponentially. By 2006 the International Labor Organization had estimated that of the 66 million workers employed in EPZs worldwide, 40 million were in China. As interest in the classic EPZ waned in the 1980s and 1990s, the zone began to breed promiscuously with other enclave formats, or 'parks', merging with offshore financial areas, tourist compounds, knowledge villages, high technology campuses, museums and universities. Rather than functioning as catalyst and dissolving into the general business and industrial climate of its host, the zone has become a persistent yet mutable instrument, transforming as it grows and absorbing more and more of the general economy within its boundaries. In the past generation, then, the zone has become a kind of petri dish for the cultivation of a host of spatial products – e.g., call centres, software production facilities, factory compounds, office parks – that easily migrate around the world and thrive in legal lacunae and political quarantine, enjoying the insulation and lubrication of zone exemptions.

Having swallowed the city whole, the zone is now the germ of a city-building epidemic that reproduces glittering mimics of Dubai, Singapore and Hong Kong. No longer in the shadow of the global city as financial centre (New York, London, Tokyo, São Paulo), the zone as corporate enclave is the most popular model for the contemporary global city, offering a 'clean slate', 'one-stop' entry into the economy of a foreign country. Economic analysts chase after scores of zone variants, even as they are mutating on the ground and oscillating between visibility and invisibility, identity and anonymity.

Surpassing irony, now major cities and even national capitals, supposedly the centres of law, have created their own zone doppelgängers like Navi Mumbai, New Songdo City, a Seoul double that developer Stanley Gale calls a 'city in a box'. New Songdo City is a complete international city aspiring to the cosmopolitan urbanity of New York, Venice and Sydney, the zone is filled with residential, cultural and educational programmes in addition to commercial programmes. In Kazakhstan, Astana, the national capital as free trade zone now replaces the previous capital of Almaty, and it is styled to send not only familiar Western signals in its architecture and urbanism, but also symbolic national heraldry as part of Nazarbayev's Paleo-Genghis competition with Dubai.

After many cycles of zone breeding around the world, recessive or unlikely traits begin to appear. Dubai Humanitarian City, as an outpost of relief agencies and NGOs, makes tenants out of the chief critics of zone politics and abuses. Qatar Education City uses the campus/park/zone model to provide a headquarters for the franchise of major universities around the world. In some ways, the zone is a strange intentional community not unlike Rome's ideal military towns, Spain's 'Laws of the Indies' for developing *pueblos* and *presidios* in the New World, or the exclaves of defecting religious organisations in the New World. The zone's golf courses inspire loyalty and bring tears to men's eyes. Its villas and skyscrapers are signs of global aspiration.

Operating in a frictionless realm of exemption and merging with other urban formats, the zone also naturally merges with the resort and theme park, even assuming an ethereal aura of fantasy. IT 'resorts' offer lush vegetation and a mixture of small-scale vernacular buildings and mirror-tiled office buildings. Even more extreme are those zones that merge with offshore island retreats. Citing Dubai, Singapore and Hong Kong as models, the island of Jeju, for instance, has transformed itself into a 'free economic city'. On the island of Kish off the coast of Iran, Kish Free Zone similarly attracts business to an island notorious for its relaxed religious standards. There is not only a loosening of headscarves and a greater opportunity for socialising between men and women, but also a standard set of exemptions to which the corporation has grown accustomed. Nearby hotels like the Dariush Grand Hotel recreate the grandeur of Persian palaces with peristyle halls, gigantic cast stone sphinxes and ornate bas-reliefs depicting ancient scenes, with palaces and resorts where petrodollars can get away to relax.

Often maintaining autonomous control over a closed loop of compatible circumstances, the zone embodies an isomorphic disposition – a naturalised form of lawlessness that rejects most of the circumstances and contradictions that are the hallmark of more familiar forms of urbanity. In its sweatshops and dormitories, it often remains a clandestine site of labour abuse. The zone is a formation within which poverty can be strictly maintained without the chaos of informal economies. Those who tend the self-referential organisations of the free zone are proud of the peaceful, robust, information-rich environments they have created. Yet only information that is compatible to a common platform qualifies for inclusion. Indeed, an enormous intelligence is deployed to reset or eliminate any errant or extrinsic information. While remaining intact, the hermetic organisation develops shrewd auxiliary tactics and strategies to fortify and defend itself against contradiction. Regimes of power at


ZHUHAI MACAO CROSS BORDER INDUSTRIAL ZONE ZHUHAI PARK


CNN


CYBER TOWERS


DUBAI INTERNET CITY


招租 13925390698
UNISON BUILDING

left column, top to bottom
Dubai Media City, Dubai, UAE, 2007.
Dhaka Export Zone, Bangladesh, 2007.
Dubai Internet City, Dubai, UAE, 2012.
Zhuhai Macao Cross Border Industrial Zone, part of the Zhuhai Free Trade Zone, China, 2009.

middle column, top to bottom
Dubai Media City, Dubai, UAE, 2006.
Dubai Internet City, Dubai, UAE, 2006.
Cyber Towers at HITEC City, the software landmark of Hyderabad, Andhra Pradesh, India, 2010.
Zhuhai Free Trade Zone, China, 2009.

right column, top to bottom
Science City, Tsukuba, Japan, 2005.
Export Processing Zone, Athi River, Kenya, 2008.
Songdo International Business District, Incheon Free Economic Zone, Incheon, South Korea, 2011.
Weill Cornell Medical College, Education City Doha, Qatar, 2006.

top – Map of the East Indies. The official trade zone (*octrooigebied*) of the Dutch East India Company (VOC) according to the VOC Charter, which was between Cape of Good Hope (South Africa) and the Strait of Magellan (South America); printed ca. 1700.

bottom – The United States' first foreign trade zone, Staten Island, New York, opened 1 February 1937.

once diversify their sources and contacts while consolidating and closing ranks, extending and tightening their territory. They grow while deleting information. Evidence of violence and exploitation often constitutes the inconvenient information that must be overlooked. This information paradox, this special stupidity, wherein an enormous amount of information is required to remain information poor – is a common tool of power.

Decades later, the poorer countries are eagerly anticipating their fresh new Special Economic Zones, or SEZs, even while their own business and technical innovations may have outgrown the form. Georgia plans to build the new city of Lazika on a swamp area near the Black Sea that it had previous promised to conserve. Turning away questions about whether the swamps can support the weight of new buildings, the city is seen as part of a new global reorientation and a means out of poverty and unemployment. Giorgi Vashadze, a deputy minister of justice 'was browsing on the Internet when he came across the idea of a "charter city", with distinct regulatory and judicial systems that could attract foreign investors to build factories'. On the other side of the world, Korean entrepreneurs have proposed a new science city called Yachay for the highlands of Imbabura north of Quito in Ecuador. Recently, a grainy video surfaced for Nova Cidade de Kilamba, the new town outside the capital city of Luanda in Angola. It moves through the streets of a city of candy-coloured high-rises, schools and retail units that stand empty in the dusty landscape. Kilamba was intended to be one of China's 'satellite cities' in Africa, but it seems to be joining a collection of Chinese ghost cities.

For all of its efforts to be apolitical, the zone is often in the cross hairs of global conflict. While extolled as an instrument of economic liberalism, the zone trades state bureaucracy for even more complex layers of extrastate governance, market manipulation, and regulation. For all its intentions to be a tool of economic rationalisation, the zone has often become a perfect crucible of irrationality. As an urban software it is the equivalent of MS-DOS.

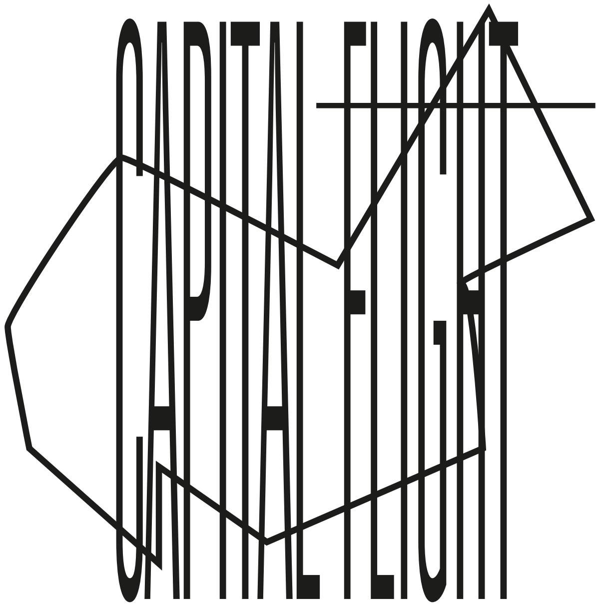
Maybe the wild mutations and spectacular irrationality are strangely encouraging. While the zone's irrationality, invisibility and discrepancy make it the secret weapon of the powerful, two can play at this game. Does the very spread of the zone make it a potential multiplier or carrier of alternative technologies, urbanities and politics? Perhaps the next zone entrepreneurs will simply ask, 'Why enclave? Why not locate some of the zones infrastructures and incentives in the city itself? Why not lead by protecting our own labour?' Zone infrastructure might be mapped directly onto Nairobi, Guadalajara, Moscow, Quito, instead of their ex-urban enclaves thus returning more financial benefits to the domestic economy. Given the zone's ambition to be a city, it potentially even carries the genetics of its own reversal or antidote.

GEOGRAPHIES OF AVOIDANCE

Bitcaves

The infrastructures of global finance are so utterly complex, opaque and scattered that they lack tangible representations to help us understand them. We can understand money because of its physical representation, yet the infrastructures through which capital circulates are a convoluted, multi-layered, global architecture of places, institutions, regulations and information networks. In this landscape 'multinationals and banks are the ultimate beneficiaries of globalization',[1] as they can be everywhere (sales) and nowhere (avoidance of legislation) at the same time. In the following section we briefly sketch three economic geographies in which the avoidance of legislation is central: dark pools, shadow banking, and the offshore economy.

1. Joseph Stiglitz, 'Globalisation isn't just about profits. It's about taxes too', in *The Guardian*, 27 May 2013.



1. Offshore

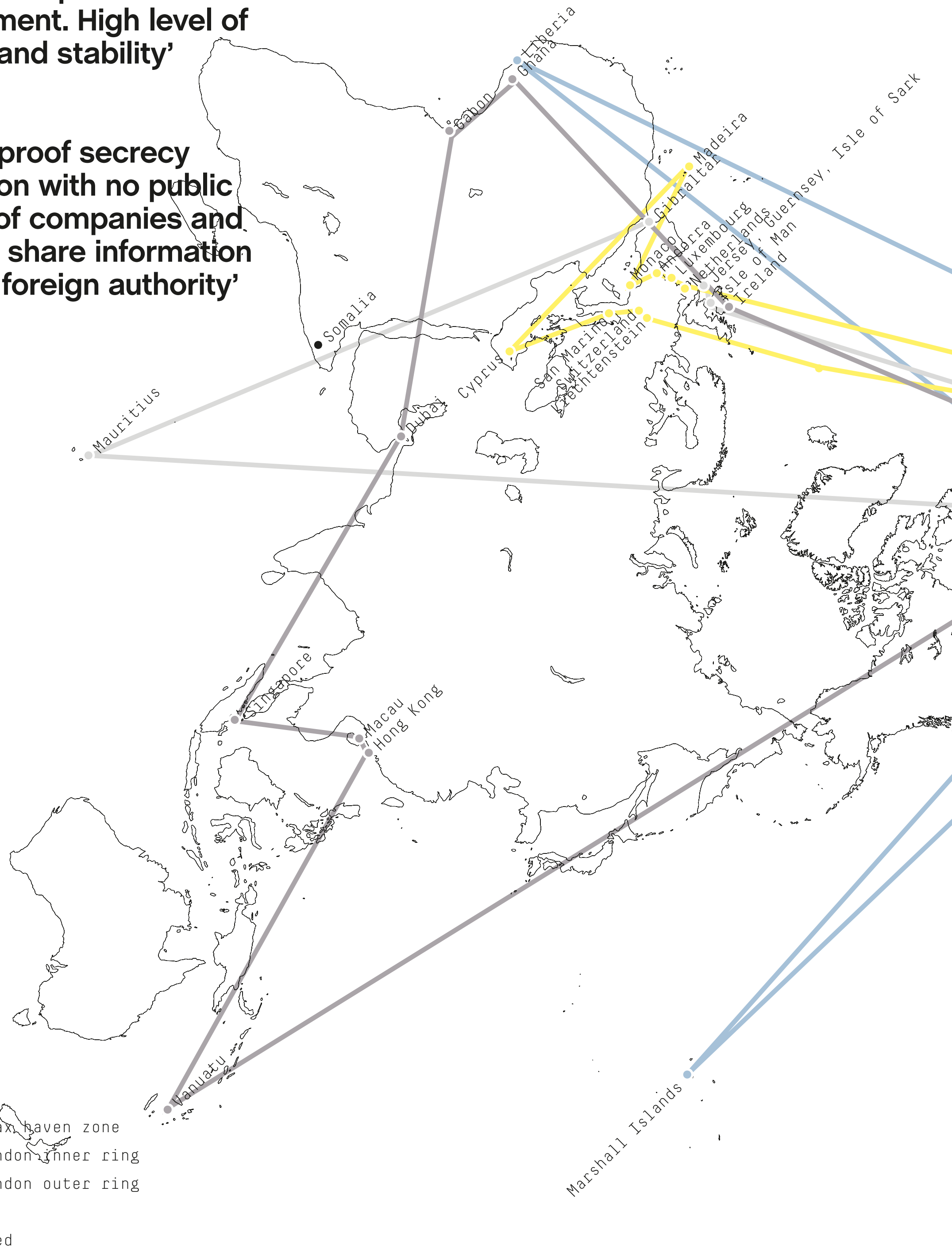
Today, tax avoidance is no longer an exception but the norm. It has created a powerful financial shadow world into which capital flows are pumped to legally circumvent financial regulation. While many governments lose tax revenues year after year, large capital sums are accumulating in offshore jurisdictions. Offshore wealth is currently estimated at 21 to 32 trillion US dollars;[2] this private financial wealth is untaxed and remains sheltered in secrecy jurisdictions beyond the reach of tax authorities. This black hole that allows banks, multinationals and wealthy individuals to escape financial regulation in their own jurisdictions is referred to as 'the offshore economic system'. This financial shadow world has operated below the radar for so long simply because it is impossible to see its core capabilities, such as secrecy, tax minimisation, access, asset management, and security, all at once. Offshore Financial Centres (OFCs) are key to avoiding onshore capital regulations. The IMF defines an OFC as a country or jurisdiction that provides financial services to non-residents on a scale that is incommensurate with the size and financing of its domestic economy.[3]

2. James S. Henry, 'The Bizarre Economics of Tax Havens and Pirate Banking', presentation at TEDx Radboud University, 2013.

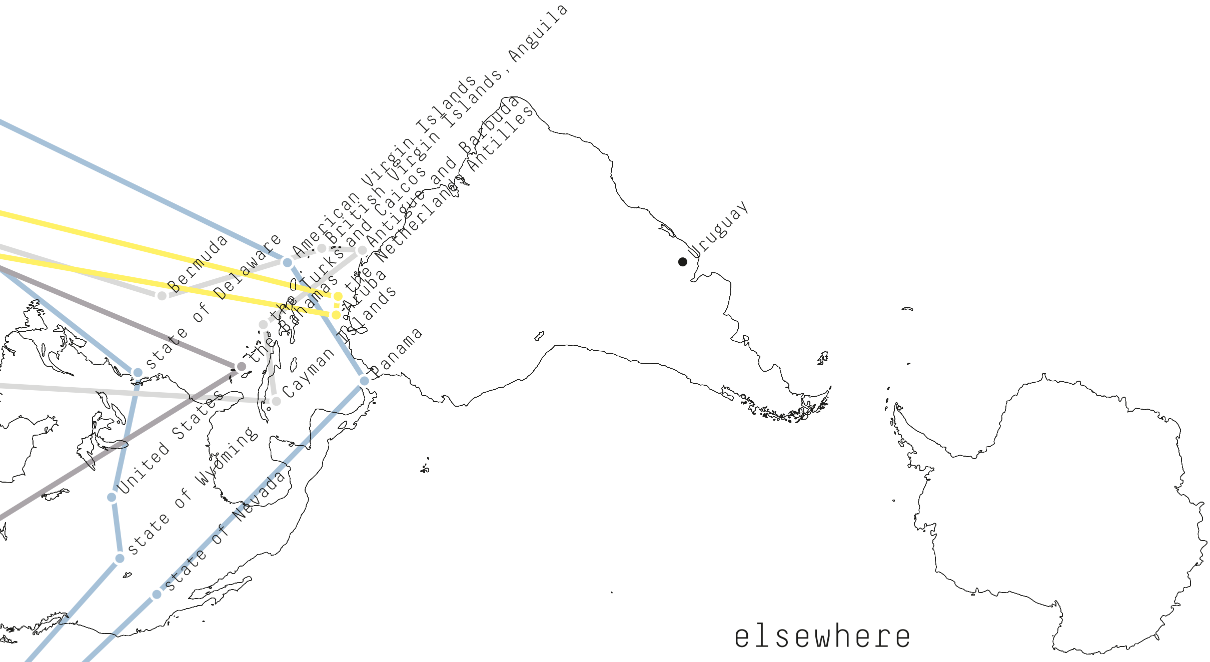
3. Ahmed Zoromé, *Concept of Offshore Financial Centers: In Search of an Operational Definition*, IMF, 2007.

Jersey —
‘Leading offshore financial centre, key base for offshore banking and private wealth management. High level of secrecy and stability’

Nauru —
‘Whisperproof secrecy jurisdiction with no public records of companies and does not share information with any foreign authority’



The offshore economy consists of offshore financial centers, conduit havens, free trade zones and about sixty secrecy jurisdictions.



elsewhere

here

REGULATED SPACE / SECRECY SPACE

nowhere

somewhere

2. New British Empire

Most of the today's tax havens were part of the former British Empire, now known as the City of London. In the late nineteenth century, colonial officials in the Caribbean and promoters of cable-connections 'crafted a politics and technology of Empire as a universal vision and God's-eye – or ear – perspective on the peoples of the world'.[4] Constructing a complex network of submarine cables between the Crown's various colonies laid the basis for today's offshore financial system. This rise of offshore financial centres coincided with the competitive deregulation of markets between the 1970s and the 1990s. These liberalising changes in the world's economies made capital more flexible and it moved to places with the least resistance. Today, this revived colonial infrastructure of cables and remote administrative outposts forms the spider web that lures in global capital and directs it straight to the City of London. The offshore economy has given rise to a 'new British Empire' that somehow slipped under the radar.[5]

4. Secrecy jurisdiction

Today the former colonial outposts of the City of London function as secrecy jurisdictions in the offshore economy. With little or no taxation, guaranteed banking secrecy and an administrative workforce they provide shelter and 'substance' for innumerable mailbox companies belonging to banks and multinationals. 'What characterises these places is their ability to create laws that can impact outside their own territories: they create a deliberate, and legally backed, veil of secrecy that ensures that those from outside that jurisdiction making use of its regulations cannot be identified as doing so'.[6] Furthermore, the small communities in these jurisdictions foster a close-knit elite. As a result, legislation can be changed quite easily if requested by foreign banks or corporations. This democratic sell-out is known as 'legislation for hire' and indicates that these places are not merely the remnants of an old empire but are economic instruments purpose-built for today's private, corporatised interests.

5. Pass-through havens

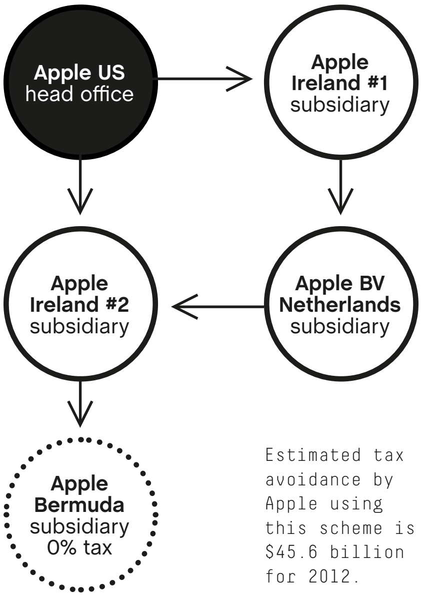
Although tax havens still have a popularised image of Caribbean islands where celebrities and mafiosi park their money, they have long ceased being an 'exotic side show' to the global economy – now they are its very core. It is wealthy OECD countries in particular that play a major role in this offshore economy and offer numerous legal opportunities to evade financial regulation. It is not untaxed capital that accumulates in these countries, but as pass-through havens they are immensely popular in tax avoidance schemes – or 'tax neutralisation' as they prefer to call it. With their professional workforce, stable infrastructure, open culture and political stability, they have become pioneers in providing legal and discrete services for escaping financial regulation. OECD pass-through havens represent the high-end of the offshore economy and lobby aggressively to avoid being portrayed as shady Caribbean tax havens.

6. Corporate zones

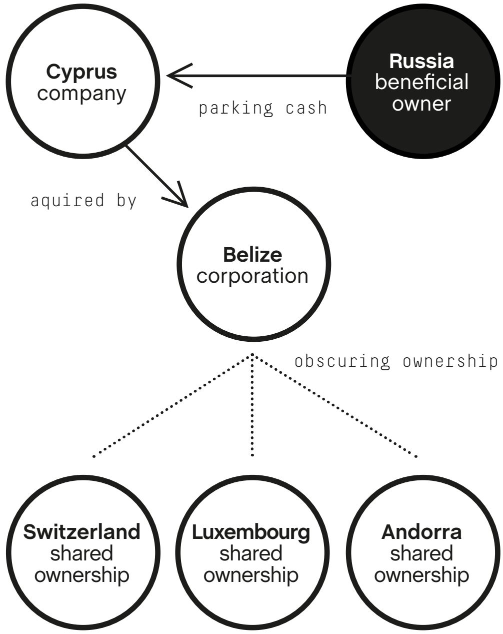
This type of tax haven aims at establishing an exclusive image of future dreams, wonder and wealth: a sanctuary from financial regulation. Corporate zones are designed with the duality of being onshore and offshore at the same time. They are situated in the territory of the nation state yet are designed as zones that facilitate the evasion of financial regulation and governance by that same jurisdiction. Examples are Ebene Cyber City in Mauritius and the forthcoming King Abdullah Economic City in Saudi Arabia.

4. Bill Maurer, 'Islands in the Net: Rewiring Technological and Financial Circuits in the "Offshore" Caribbean', in *Comparative Studies in Society and History*, July 2001, vol. 43 no. 3, p. 472.
5. Nicholas Shaxson, *Treasure Islands, Tax Havens and the Men Who Stole the World*, London: The Bodley Head, 2011.
6. Tax Justice Network, *Mapping the Faultlines. Defining the Secrecy World*, 2009.

DOUBLE IRISH & DUTCH SANDWICH



Estimated tax avoidance by Apple using this scheme is $45.6 billion for 2012.



CYPRUS SANDWICH

7. Fiscal branding

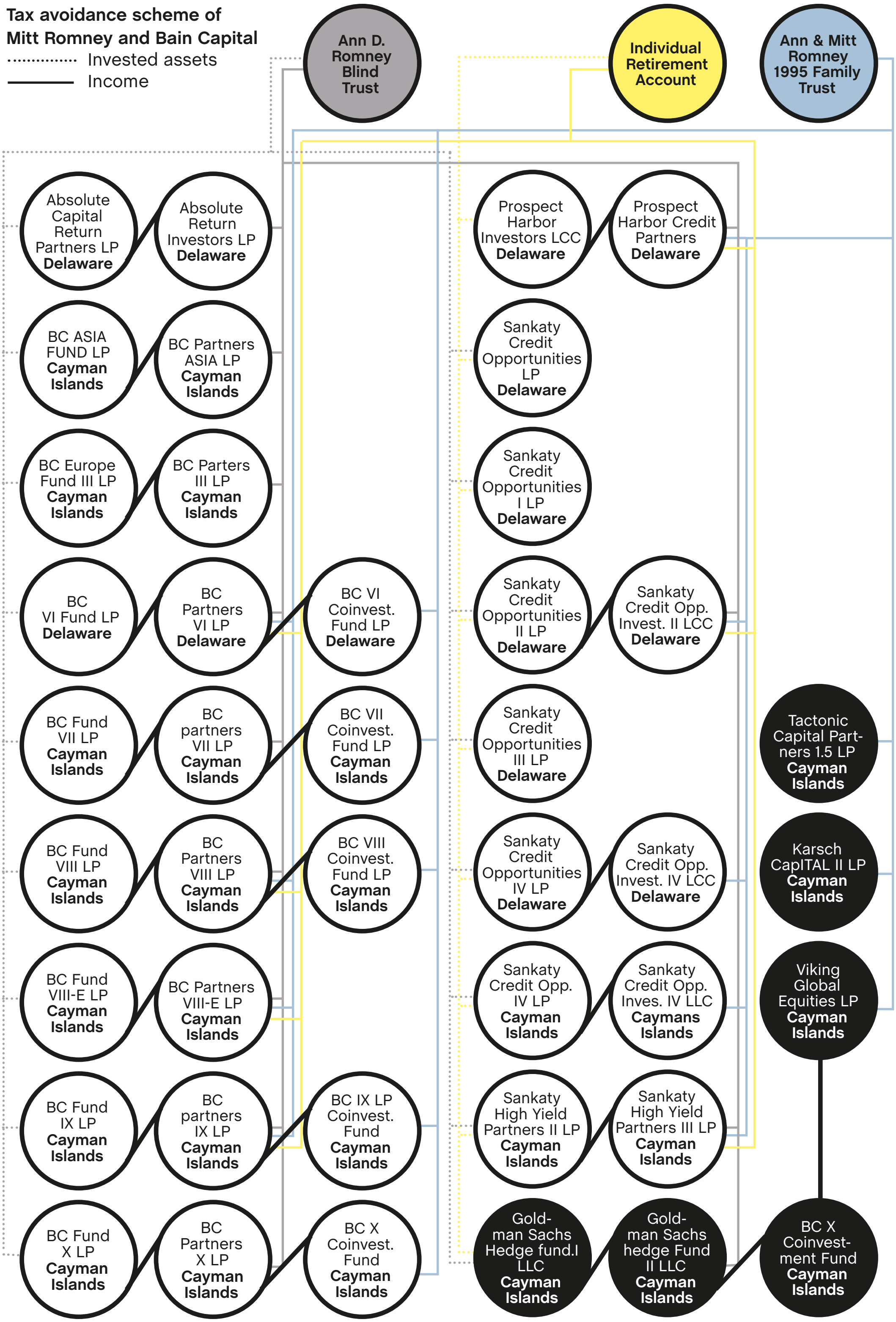
Although the offshore system is fully integrated into our mainstream economic system, we do not live in a uniform financial economic world. There are different regulations and rates all over the world when it comes to where and how capital is taxed and parked. In the global competition for investment, avoiding financial and legal regulations has become vital to 'place- or nation-branding' strategies. Nation states increasingly lower their corporate taxes to attract investment and fiscal place- or nation-branding accelerates this race-to-the-bottom even further. In a promotional video of the Netherlands Foreign Investment Agency, supermodel Doutzen Kroes appears above a banner that reads: 'Favorable fiscal climate'. In addition to a supermodel, tax avoidance is the most popular and fashionable Dutch export product of today.

8. Sandwich schemes

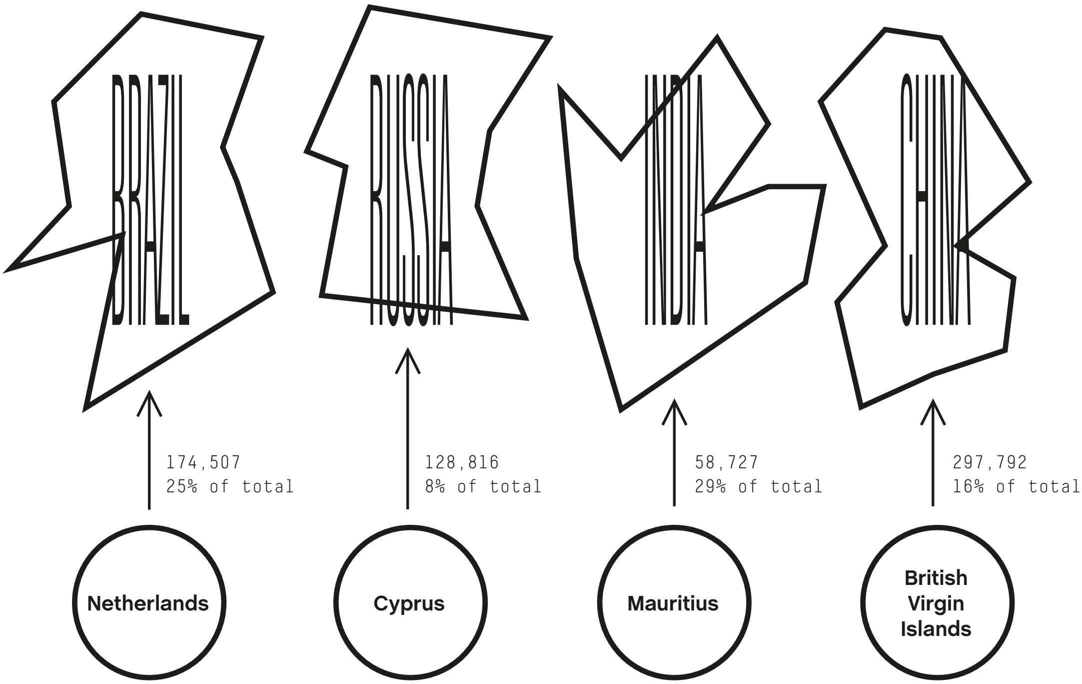
Tax sheltering, tax planning, tax neutralisation, tax relief – all these are names for the same thing: aggressively avoiding tax obligations in technically legal ways. Fiscal lawyers and accountants are crucial to this business since they design and facilitate tax avoidance schemes. The Big Four – the worlds largest international accountancy firms – Ernst & Young, KPMG, Deloitte and PWC, have created 79 tax avoidance schemes since 2009.[7] Apparently the names of these schemes are conjured up during business lunches: tax can be avoided by means of a 'Dutch Sandwich', a 'Double Irish' or a 'Cyprus Sandwich'.

7. Alexi Mostrous, 'Top firms behind 1 in 5 schemes to avoid tax', *The Times*, 31 January 2013.

Tax avoidance scheme of Mitt Romney and Bain Capital



Sources of Inward Direct Investment in BRICs
(millions of US $)



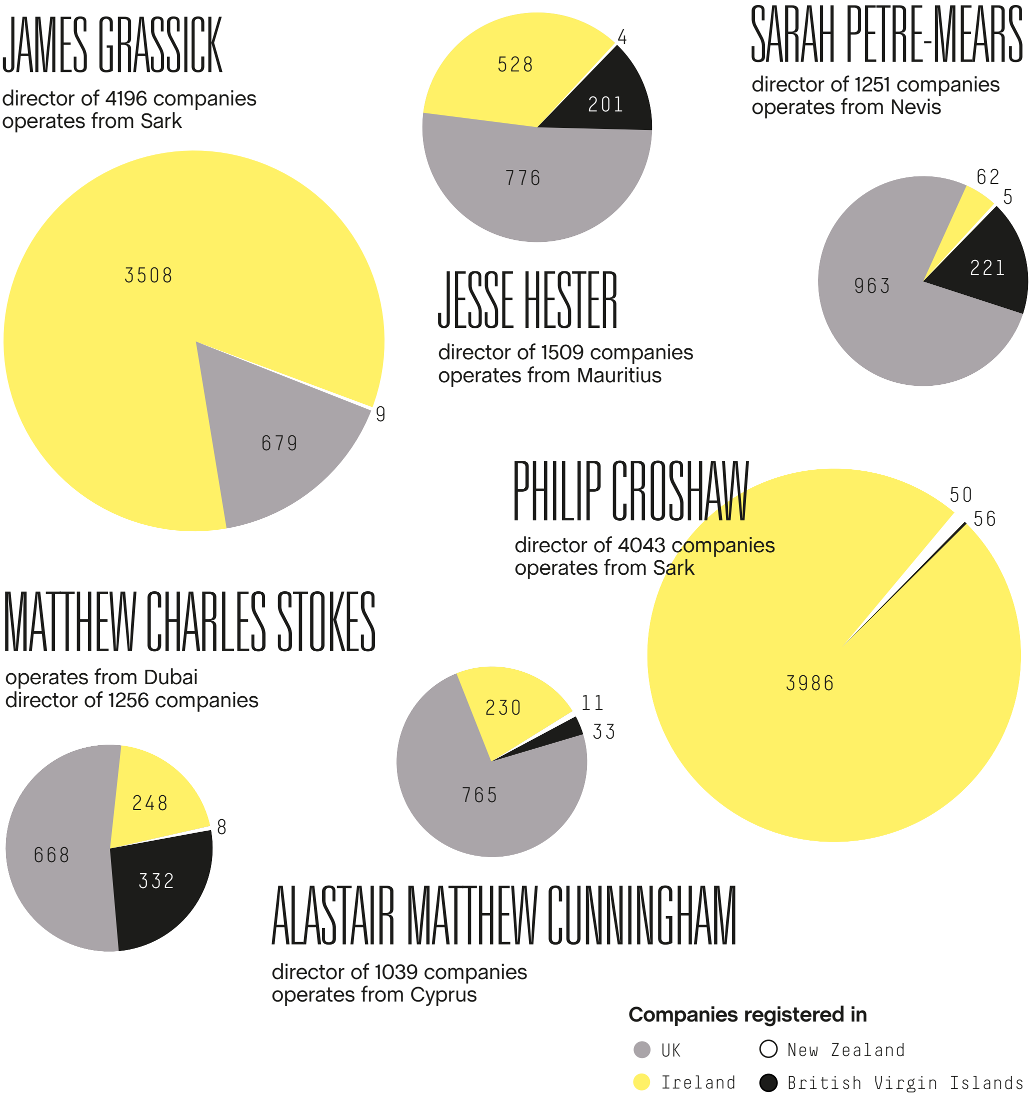
9.
Mitt 'R-Money'

Mitt Romney's fortune of an estimated $250 million is largely a black hole. By using complex tax-dodging tricks he has been able to keep his effective tax rate at roughly 13% over the last decade. In August 2012, Gawker.com published a massive cache of 950 confidential internal audit documents on 20 secretive hedge funds and investment vehicles in Delaware and the Cayman Islands in which Romney had invested more than $10 million as of 2011, while only declaring $913,300 as income. Based on those documents this graph maps out which of these entities are affiliated with Bain Capital, the private equity firm Romney co-founded in 1984. Besides having 138 secretive offshore funds registered in the Cayman Islands, Bain Capital also has offices in the Netherlands and Luxembourg.

10.
BRICs

The enormous amounts of capital that are invested in BRIC countries are actually strongly related to losses in tax revenues in the same countries. Multinationals and wealthy individuals in Brazil, Russia, India and China move their capital offshore to avoid paying onshore tax. Eventually they bring their 'capital back home dressed up as foreign investment to disguise the source of the funds'.[8] As a result, the largest investors in each of the four emerging economies are tax havens: the Netherlands in Brazil, Cyprus in Russia, Mauritius in India, and the British Virgin Island in China. The incoming 'investments' from tax havens imply that foreign investment numbers in the BRIC are more positive than they actually are.

8. Naomi Rovnick, 'Most foreign investment in BRICs isn't foreign at all—it's tycoons using tax havens', *Quantz*, 26 March 2013.

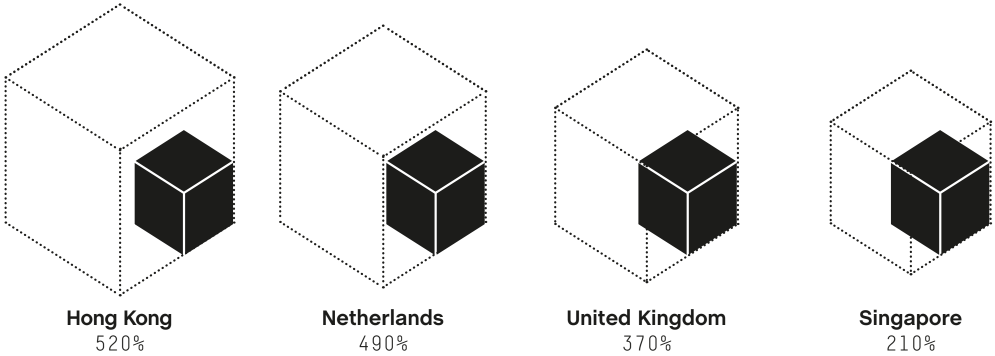


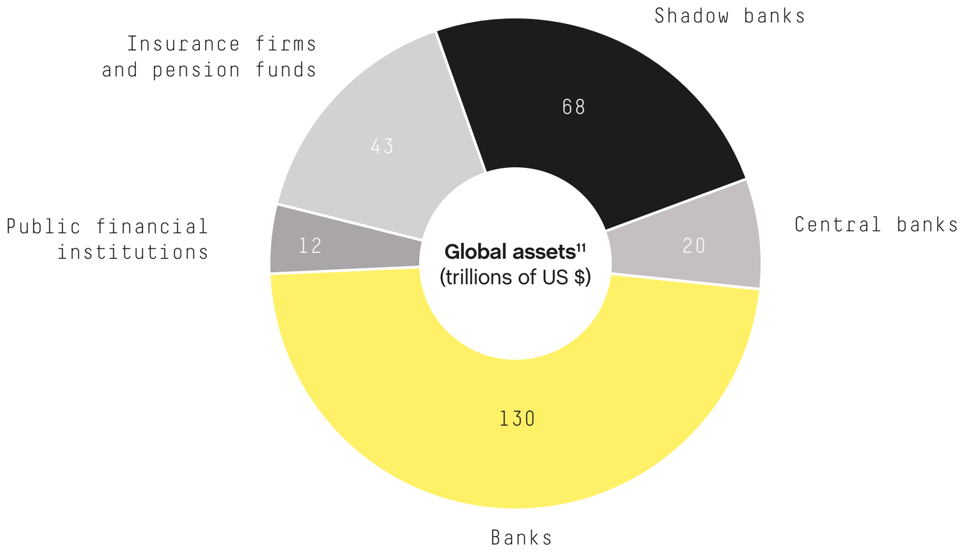
11.
Substance

Most companies in tax avoidance schemes are 'shell corporations' or 'mailbox companies' that only exist on paper and do not have a physical presence. Often thousands of them are registered at a single address; apparently 18,857 'companies' are 'hosted' – or at least registered in Ugland House, a small building on the Cayman Islands. But regardless of whether it is in the Cayman Islands or Amsterdam, the daily administrative practice of tax avoidance goes unnoticed. Trust offices provide companies with substance such as administrative bookkeeping, a post address, local staff and a CEO. The names of some of these companies are unreadable or unpronounceable, further underscoring the fact that they only exist on paper. In addition, the number of companies that have trust office staff as their CEO is astounding. More than 21,500 companies use a network of only 28 nominee CEOs – or 'sham directors' as they are called. They sell their name for use on official documents, using addresses in obscure locations all over the world.[9]

9. James Ball, 'Offshore secrets: how many companies do "sham directors" control?', *The Guardian*, 26 November 2012.

Countries with most shadow banking[10]
(relative to GDP)





12.
Shadow banks

Shadow banks are financial intermediaries such as hedge funds, money market funds and structured investment vehicles that are involved in credit creation across the global financial system but are not subject to regulatory oversight. The shadow banking system has escaped regulation simply because it does not accept traditional bank deposits, but finances it's activities through short-term investor credit. As a result they create dangerous systemic risks. The largest shadow banks are traditional banks.

13.
Pirate banks

Pirate banks are offshore accounts often located in secrecy jurisdictions such as Switzerland or Jersey that are funded electronically and use advanced technology to make it more difficult to identify the bank account and trace the chain of ownership.

10. 'Global Shadow Banking Monitoring Report 2012', Financial Stability Board, 18 November 2012.
11. Source: National flow of funds data.

Evocative names of aggressive trading algorithms in dark pools.

GUERILLA	ICEBERG	STEALTH	BASOR
developed by Credit Suisse	developed by Goldman Sachs	developed by Deutsche Bank	developed by Quod Financial
DAGGER	SNIPER	BLAST	SNIFFER
developed by CITI	developed by Goldman Sachs	developed by Credit Suisse	general term

14. Black box trading

Stock markets used to be physical locations where floor traders were involved in *open outcry*. 'Market makers were able to sense which way the market was going simply by looking around them, staring into the nervous eyes of another trader, watching a competitor frantically rush into a pit and start selling, or buying.'[12] With electronic trading that physical sense of market flow disappeared.But the market gained new eyes – electronic eyes. Investment banks designed hunter-seeker algorithms such as *Stealth*, *Sniper*, *Guerrilla* and *Sniffer* that, like radar, could 'detect' which way the market was going. Robot trading algorithms can respond to markets more rapidly and outperform human traders. The seismo-graphic squiggles they leave behind on the screen have become the new face of the market.

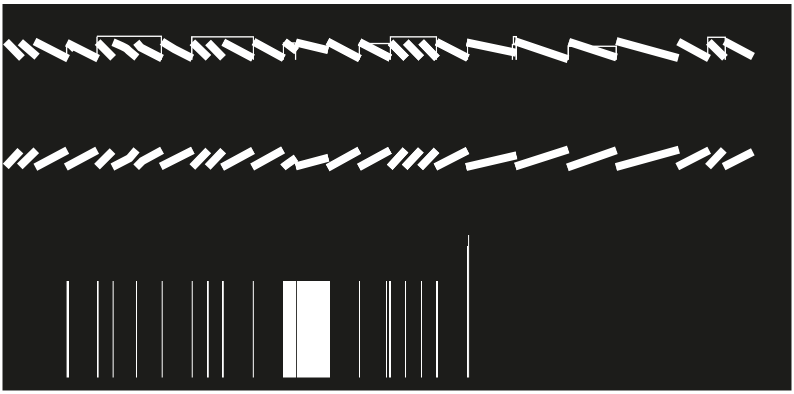
15. High frequency trading

High frequency trading is a special type of black box in which algorithms trade stocks at the speed of light. There is no interest in actually owning stocks. An investment position may be held for seconds or fractions of a second only, the intention being to re-sell at profit, with computers trading in and out of positions thousands or tens of thousands of times a day. The tiniest delay can make the difference between a loss and a profit.

12. Scott Patterson, *Dark Pools, The Rise of the Machine Traders and the Rigging of the U.S. Stock Marke*t, New York: Crown Business, 2013.

Drawings representing 'quote stuffing' patterns – a high frequency trading tactic – that were detected during the Flash Crash of 6 May 2010.

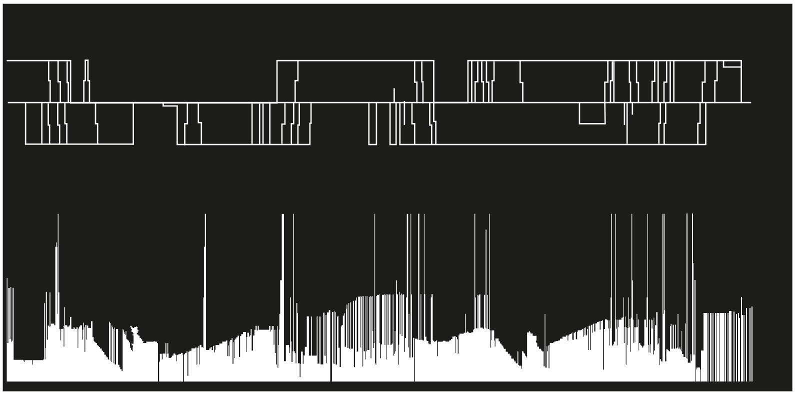
Ask Mountain

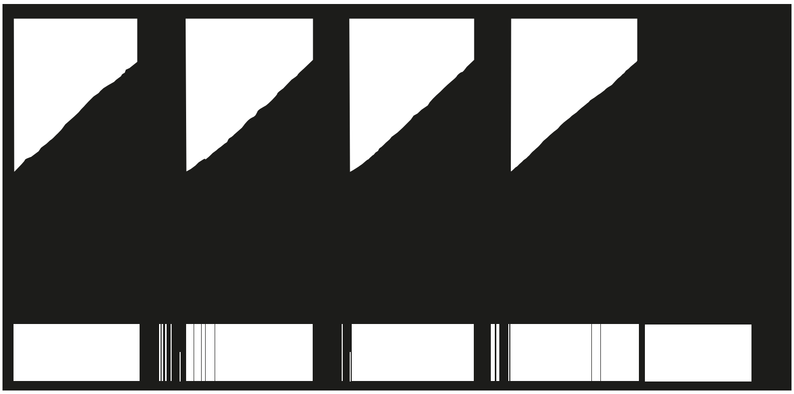


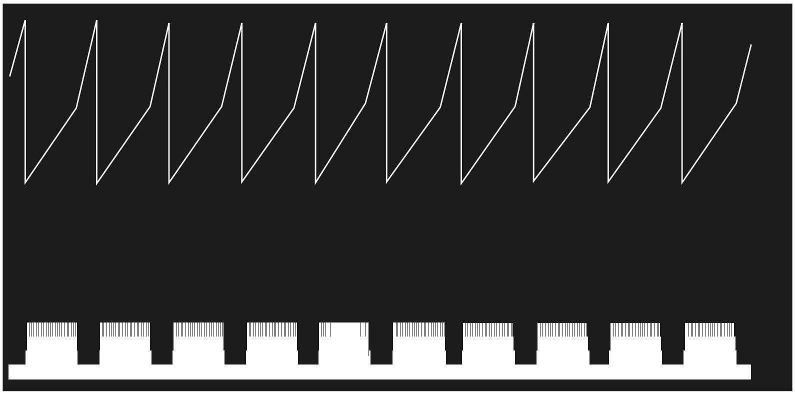
Zanti Mayhem III

Blotter

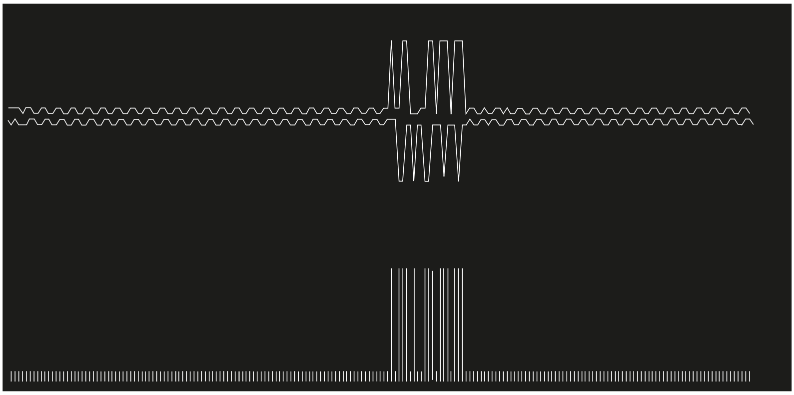

The Ramp


Robot Hunting

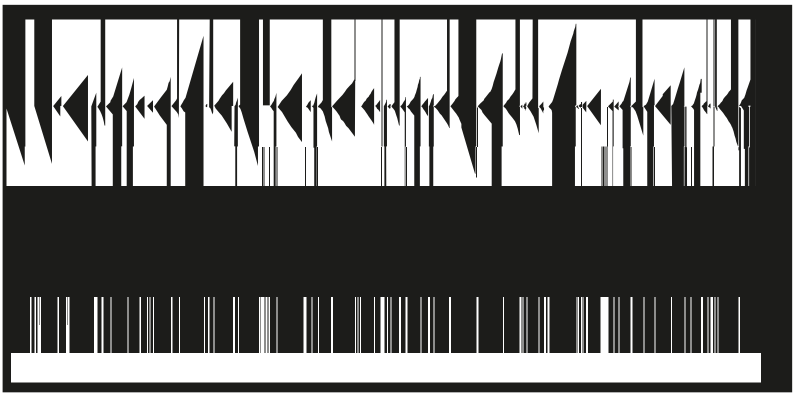

CancelBot



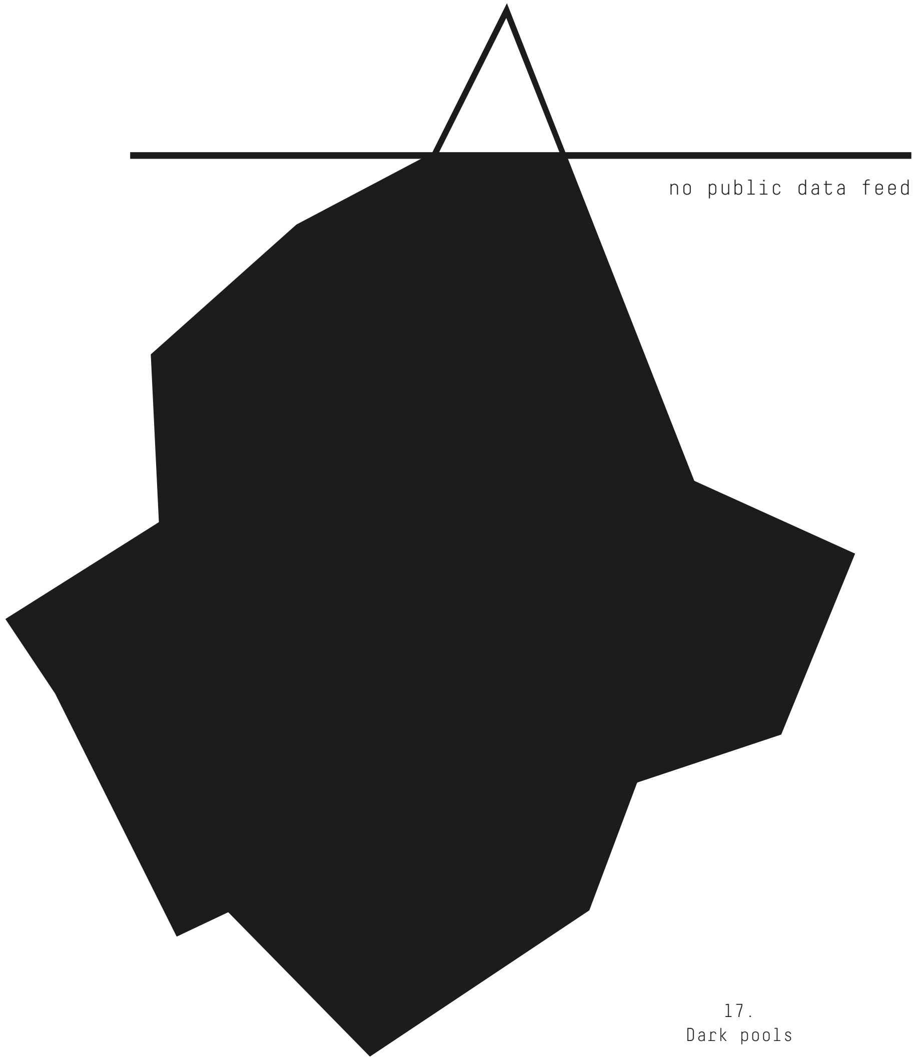
Eraser Head



Zapper Clone



Scofflaw



16.
Iceberg order

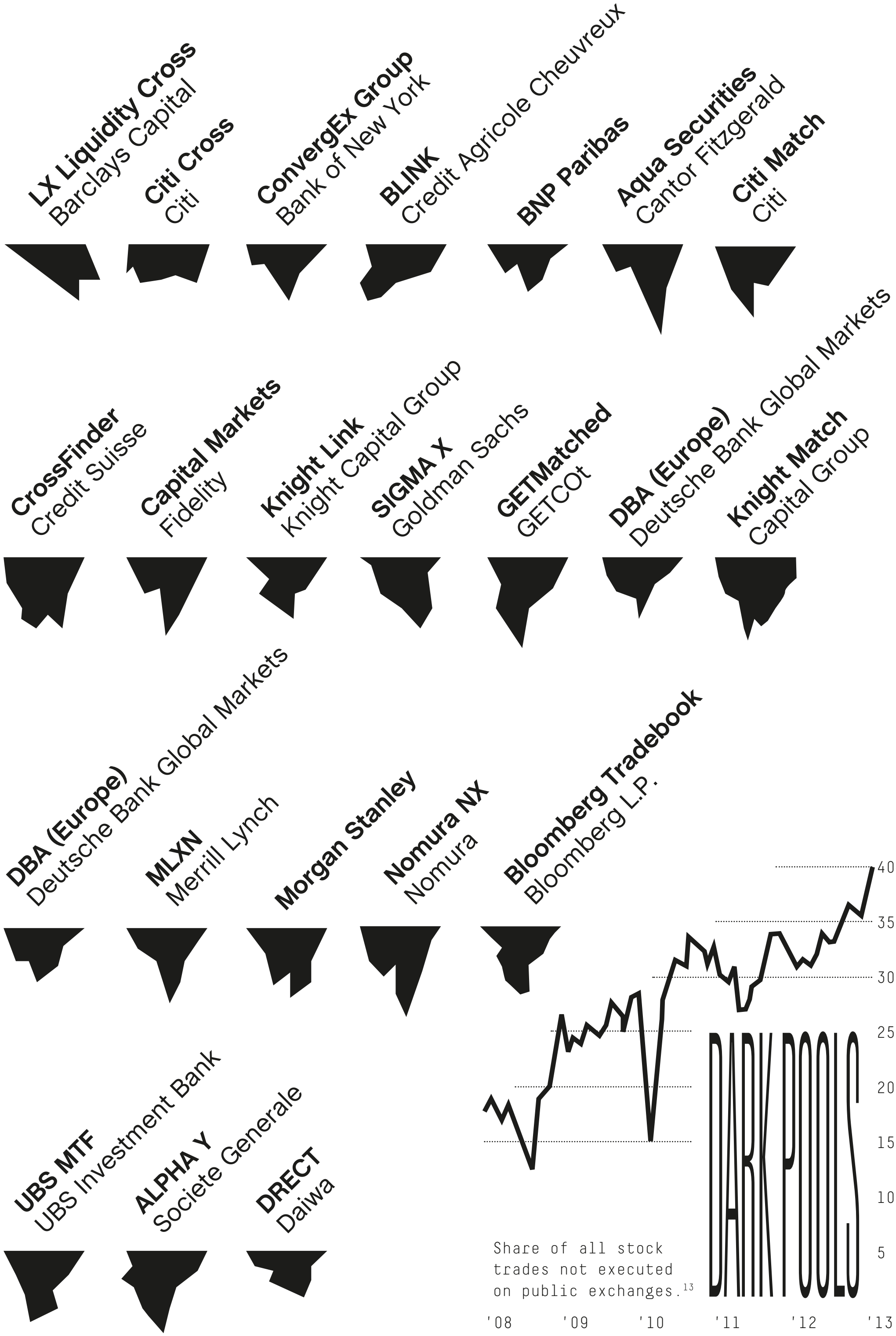
Decentralised, screen-based trading enabled more investors and traders to act on their own behalf instead of issuing orders to brokers. New Direct Market Access (DMA) strategies began to develop. Chopping up a large order on the public exchange into smaller pieces is the most straightforward strategy. This is done to disguise large orders from other traders, as the market would likely react to the existence of one large buyer or seller. Because only a small part of the order can be identified and the rest remain hidden, this strategy is called an *iceberg order*.

17.
Dark pools

Dark pools are private trading platforms that are concealed from public view. These platforms create an anonymous space that enables large investors to conceal their activities on the market. Dark liquidity pools are less regulated than public exchanges and do not have to announce their intentions to the market. This prevents large investors from influencing the market and inflating stock prices. Dark pools are often run by large investment banks that also trade in the pools themselves. Off-exchange trading in dark pools increased from 16% in 2008 to 40% in 2013.[13]

13. Nathaniel Popper, ‘As markets heat up, trading slips into shadows’, *New York Times*, 31 March 2013.

Dark pools
Broker-dealer-owned



UNVEILING A DARK UNIVERSE

Brigitte van der Sande

Trevor Paglen works in between the fields of art, photography, geography and investigative journalism. Working on *The Other Night Sky*, in which he used data of amateur satellite observers to track the orbits of satellites, Paglen realised that human presence would be everlasting in the ring of machines that orbit the Earth. This led to his project *The Last Pictures*. Working on this project Paglen had a text on his studio wall: ‘How is it that we knew exactly how we were going to kill ourselves, and went ahead with it anyway?’ He thought about the Rapi Nui people on Easter Island, who felled the last tree to make the rope with which they could erect the last monolith, one of the iconic statues on the Easter Island that look up toward the sky. This essay is based on an interview by Brigitte van der Sande with Trevor Paglen, and on Paglen’s masterclass and lecture at Sonic Acts 2013.

Photography and the dark world

Trevor Paglen studied geography after finishing art school, because he was fed up with the Greenbergian 'art for art's sake' attitude in the photography world. Professional photographers blame digital technology for the crisis in photography – on Facebook there are now 170 billion photos, in 2012 approximately 350 billion photos were taken. A new fetishism about which type of film to use is moving photography more and more into the direction of painting. To Paglen this is a dead end. He finds it much more rewarding to think about what it means to make pictures from a perspective that is more than representational. Paglen started studying geography because he wanted solid scientific knowledge, and time to research his interest in what is seen and what remains unseen. According to Paglen, we tend to look inside the frame and neglect the outside. Traditional photography theory doesn't help to interpret unseen phenomena, as with the unseen the question is not about what is real and what is mediated. For Paglen, the 21st century will be the century of photography as a vernacular medium about everyday life, used by amateurs and professionals alike. Photography is a technical a priori for the way we see the world, which also includes seeing with machines: spy satellites, recognition cameras, GPS chips in cell phones, and the software, algorithms, laws and politics of these infrastructures.

Geography gave Paglen a theoretical framework to analyse the way humans have changed the Earth, and as a consequence how that changes us. He calls this relational geography. It raises the issue of the inbuilt ideological scripts of the machines we use, also the seeing machines. In Michel Foucault's book *Discipline and Punish. The Birth of the Prison* (1975), the architecture of the panopticum is not representational, it is a seeing machine. The prisoner never knows when he is being watched; the constant possibility of observation creates a space of discipline within the body of the inmate. Another example of seeing machines are the predator drones, flying cameras with missiles that not only produce images, but also non-geographical, relational spaces. In 'Space as a Key Word',[1] the geographer David Harvey distinguishes relational space, following Leibniz, from Cartesian absolute space, and Einstein's relative space. Harvey writes 'The relational view of space holds there is no such thing as space outside of the processes that define it. Processes do not occur in space but define their own spatial space'. Following Harvey, Paglen asks himself if it is possible to design a more

1. David Harvey, 'Space as a Key Word', paper for the 'Marx and Philosophy Conference', 29 May 2004.

democratic camera. Can we develop a different kind of political and social script for these seeing machines?
All of Paglen's projects are about the contradiction between what is invisible on the surface, and what the surface reflects. The starting point for *Blank Spots on the Map. The Dark Geography of the Pentagon's Secret World* – a book on the shadow world of clandestine military bases, secret prisons with ghost prisoners and hidden laboratories – was to find the contradiction between the logistics of disappearance and the light that every surface on the Earth reflects. Secret planes, for example, are built in real factories, secret geographies need secret logistics, but their existence leaves traces in the real world. There are fake companies, front offices that need addresses, boards, documents that are public. Through the analysis of public flight plans, we are able to trace secret flights. Even secret rocket launches are announced publicly, because they don't want to start a nuclear war by accident. What Paglen tried to show is how these covert operations tend to sculpt the state around them in their own image.

The Last Pictures

Working on the project *The Other Night Sky,* in which Paglen used data from amateur satellite observers to track the orbits of satellites, he realised that human presence would be everlasting in the ring of machines that orbit the Earth, even after the end of humanity. In billions of years thousands of satellites would remain as the last monuments of civilisation, in what he calls 'The Age of Space Artefacts'. Though he doesn't believe in the existence of aliens, let alone the possibility of aliens finding these space artefacts, he put himself in their position, wondering who left these artefacts in space, and what had happened to them.

Paglen proposed attaching a cultural artefact to a satellite when the New York based public art organisation Creative Time asked him to produce an artwork on space. The led to *The Last Pictures*. After an extensive research period, hundreds of interviews with scientists, artists and philosophers, he selected 100 pictures from the thousands that he and his team had collected. In November 2012 the EchoStar XVI mission, with Paglen's artefact – a disc with 100 images – attached to it, was launched into geostationary orbit at 36,210 kilometres above the equator, delivering direct-broadcast satellite signals back to Earth for the following fifteen years. After its life as a broadcaster, the satellite will orbit the Earth for ever after.

The disc contains 100 images without any text; the publication *The Last Pictures* provides context for us humans still alive on Earth. In the caption to the image of seventeenth-century polymath John Wilkins who attempted to develop a universal language, Paglen quotes Borges: 'It is clear that there is no classification of the universe not being arbitrary and full of conjectures. The reason for this is very simple: we do not know what thing the Universe is'.[2] The history of mankind shows that all the attempts to understand the Universe are doomed to fail.

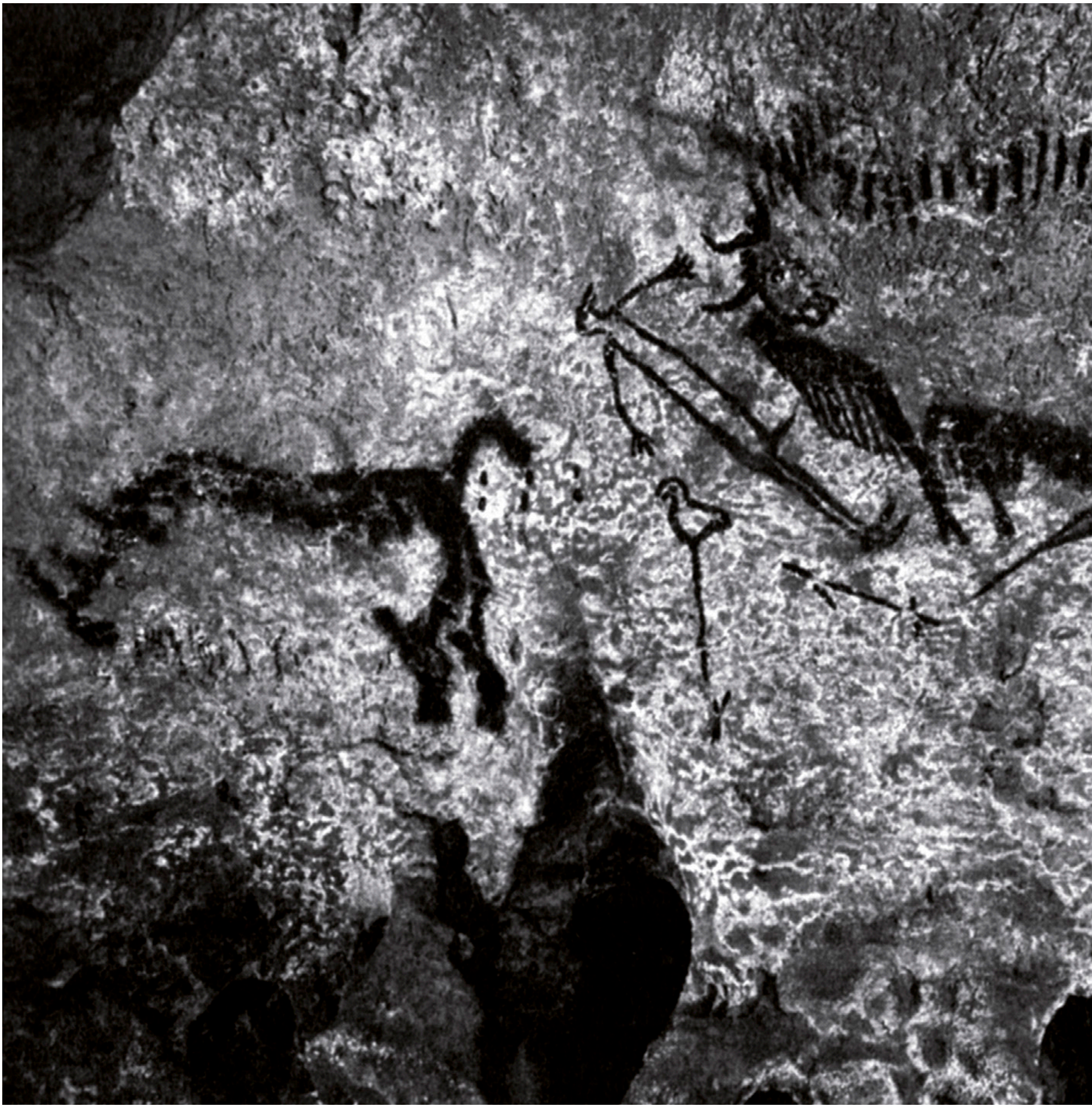
To select his images, Paglen needed rules. This is why he set up a research group of five people from different backgrounds. They looked for instance at historical models like cuneiform, messages in a bottle, eighth-century Islamic astrolabes, cybernetics, cloning, medieval bestiaries, mathematical systems and cyberwarfare. They saw tens of thousands of images, knowing that whatever they selected could only offer a partial perspective of the Earth. Some objects and images recurred so often that they became touchstones for their thinking processes, like the series of messages to aliens from the 1970s.

A dark thought experiment they often discussed was the Waste Isolation Pilot Plant (WIPP) in New Mexico, an underground nuclear waste chamber. In 1981, the US Department of Energy and Bechtel Corporation invited scientists (some of whom had worked on the alien projects), anthropologists, semioticians and science fiction writers to develop a warning sign to ward off humans in the future. Concepts varied from gigantic spikes warning off trespassers to warning texts in many different languages or a star chart showing the diminishing contamination over 26,000 years. The most intriguing concept, according to Paglen, came from semiotician Thomas A. Sebeok, who proposed assembling a priesthood who would invent stories and myths that would be passed on from generation to generation.

The Paleolithic cave paintings in Lascaux, in particular the painting usually referred to as *The Pit* or *The Shaft*, gave Paglen another insight into the function of the images in *The Last Pictures*. *The Pit* is the only pre-historic painting with a humanoid, it shows a bison with its head down and tail up, a circular shape under its belly, a stick figure with a bird-like head and an erection, a bird on what looks like a stick, and a rhinoceros with six dots in two rows under its tail. Paglen found the painting utterly unknowable and alien, a painting not made for its own time, but for us. A scene of violence, a message for the future, a frozen moment from a troubled history. On the other hand, Paglen said, the artist may have decided to paint an 'insane' image, realising the absurdity of the gesture. *The Pit* shows us that images are limited and can't explain anything if you do not know the context. For Paglen it is not a question if *The Last Pictures* will be a failure, but if it can be an interesting failure. Paglen:

2. Jorge Luis Borges: 'The Analytical Language of John Wilkins', in Jorge Luis Borges, *Selected Non-fictions* (ed. and trans. by Eliot Weinberger), London: Penguin, 1999.

Detail of painting known as *The Pit* or *The Shaft*, Lascaux cave, France. One of 100 images nano-etched onto an ultra-archival disc in perpetual Earth orbit since 2012. *The Last Pictures* project, Trevor Paglen, 2012.



Grinnell Glacier, Glacier National
Park, Montana.
top - in 1940.
Bottom - in 2006.

top – Illegal migrants as seen by a predator drone along the US-Mexico border.
bottom – Waterspout, Florida Keys.

top – Charles and Ray Eames, *Glimpses of the U.S.A*, American National Exhibition, Moscow World's Fair, 1959.
bottom – A typhoon strikes in Japan, 20th century.

‘I decided that the artefact that I was planning could only be a grand gesture about the failure of grand gestures’.

An archive of a dark world

After interviewing scientists, artists, philosophers and others, Paglen and his team collected a stacked deck of hundreds of images that were conceptually interesting. They used aesthetic criteria to get from that big stack to the final 100 images. The images had to work individually, but also together, through formal relationships. The number 100 was based on a technical criterion: you can see the pictures on the disc with your own eyes; you do not need a complicated decoding machine. Paglen included various histories of vision, like a nineteenth-century operating theatre and the Charles and Ray Eames 1959 multi-screen installation *Glimpses of the U.S.A.* for the National Exhibition in Moscow; images of states and their regulations, like IDs and fingerprints; and images of changes made to the surface of the Earth: hydraulic mining, railways, the Great Wall of China. Paglen and his team also selected pictures that show human changes to the biosphere, like the genetically modified fruit fly that has legs on its head instead of antennae; or the honeybees strapped to portable bomb-detecting devices, making them living bomb sensors.

Initially they decided to not include any images of humans, as *The Last Pictures* was not intended to be an archive representing humanity. But even if they had removed pictures with humans altogether, they still would be present as traces in the depicted artefacts. Not to show humans would be a vain gesture, implying that people could step outside of themselves. But the question remains: do these images tell us who humans are and what they do?

The book *The Last Pictures* offers a context to the selection process with a number of articles by Paglen and others involved in the project. Some of the pictures have elaborate captions, others only a short description without a location or year. The sources of the images are never mentioned. Paglen presents the ‘naked’ pictures with a kind of Benjaminian sense of disruption, refusing clear meaning and coherence and therefore easy consumption. He shows where the images fail, where they contradict themselves. He wants people to look at the pictures and make their own story. The pictures undermine their own truth claims; they offer a political or aesthetic moment that is not immediately clear. This is why he also chose pictures taken from far away; they are a device for alienation, their vantage point allows us to see ourselves from a distance. Without context, what can an alien make of them in a distant future? The images are, like the painting *The Pit* in Lascaux, unknowable.

Walter Benjamin obviously plays a key role in Paglen’s thinking about the archive. *The Last Pictures* opens with Paul Klee’s drawing

Angelus Novus reproduced in Benjamin's text 'On the Concept of History', written just a few months before his suicide in 1940.[3] Walter Benjamin calls this angel 'The Angel of History', blown into the future by the storm called progress. With his back to the future, the angel faces the past, a catastrophe. It is typical that Paglen does not show the drawing of the angel itself, but the reverse side of it. As this is the first image, we are looking at the end of history. Benjamin turned against the nineteenth-century concept of a historical progress of mankind, and introduced the concept of *Jetztzeit* (now-time) to blast open 'the continuum of history'. The explosive force of the dialectical image brings the present to a critical state. *The Last Pictures* is Paglen's acknowledgement that the future does exist as something that will last billions of years. The crucial question for Paglen is: How do we sculpt this, how does this sculpt us?

In his lecture at Sonic Acts (2013) Paglen claimed not to take an ethical position in *The Last Pictures*. He said was neither optimistic nor pessimistic about humanity. But the images in *The Last Pictures* reveal a dystopian view of the human presence on Earth, especially if you compare them to the Golden Records that were sent into outer space with the Voyagers in 1977. The Golden Records contain only utopian images and happy people: no wars or disasters. Paglen, who spent years thinking about the Golden Records, gradually became more positive about them. He finds it too easy to criticise them. One of the people working with Paglen on the research for *The Last Pictures,* biologist Susan Oyama, pointed out that the things that most threaten human existence on Earth: global warming, ecological destruction, nuclear radiation, are difficult to represent in an image. What does a picture of capitalism look like?

Paglen included a few seemingly optimistic pictures in *The Last Pictures*: laughing girls, a cherry blossom, a dandelion, a field of flowers, a few moments of solace. As every memento mori, these images remind us of life, not of death. But these moments of solace have a dark side: the laughing little Japanese girls were interned with their parents for three years by the United States government during WWII. The dandelion is a clone. The last picture in *The Last Pictures* is a photo of a field of flowers. It was shot by a photographer who, seeing the atrocities committed in a Soviet Gulag camp, turned his back in horror.

3. Walter Benjamin, 'On the Concept of History', in *Illuminations* (ed. Hannah Arendt, trans. Harry Zohn), New York: Harcourt, Brace & World, 1968, pp. 253–64.

BIOGRAPHIES

Arie Altena (NL) is a member of the Sonic Acts curatorial team. He studied literary theory and regularly writes about art and technology.

Anil Ananthaswamy (IN) is a science journalist and author. A consultant for *New Scientist*, he has also written for *Discover* and is a columnist for PBS Nova's *The Nature of Reality* blog. He is the author of *The Edge of Physics* (2010), a book that explains how some of Earth's remotest locations are crucial to our studies of the universe. *The Edge of Physics* was voted the best physics book of 2010 by Physics World (UK).

Nicky Assmann (NL) is an artist and a member of the Sonic Acts curatorial team.

Mirna Belina (HR) researches, writes and curates in the fields of experimental film and new media art.

Justin Bennett (UK/NL) works with audio and visual media. His work painstakingly examines the sounds of our everyday urban environments in the minutest detail.

Matthew Biederman (US) is an interdisciplinary artist working across media and milieus, continents and communities. His pieces explore perception, aesthetics, data systems, media saturation and its politics.

Bitcaves (NL/DK) is a design and research collective based in Amsterdam, consisting of Femke Herregraven and Nina Støttrup Larsen. Bitcaves' work traverses the contemporary realms of global finance, geopolitics, network power and information politics. In the ongoing project *Geographies of Avoidance* they explore the offshore system and avoidance of financial regulations.

Andrew Blackwell (US) is a journalist and filmmaker living in New York City. His work as a documentary editor and producer has been seen on PBS, the BBC, NPR, the *New York Times* online, at the Museum of Modern Art in New York, and at film festivals around the world. In 2010, he received an Emmy award for his work as a producer and editor of the television programme *Dan Rather Reports*, and in 2011 the New York Foundation for the Arts selected him as a fellow in non-fiction literature. *Visit Sunny Chernobyl (and Other Adventures in the World's Most Polluted Places)* (2012) is his first book.

Peter Bruyn (NL) is a music journalist.

Michael Doser (AT) is a research physicist at CERN, the European Centre for Nuclear Research in Geneva, Switzerland, who is specialised in working with antimatter, using it either as a tool (to study strong interaction), or as an object of study itself (formation of anti-atoms, study of matter-antimatter asymmetry, measurement of the gravitational interaction between matter and antimatter). For several years, he has also worked with other scientists to investigate if antimatter could be used to more effectively irradiate and kill tumours.

George Dyson (US, CA) is an historian of technology whose interests include the development and redevelopment of the Aleut kayak (*Baidarka: The Kayak*, 1986), the evolution of digital computing and telecommunications (*Darwin Among the Machines*, 1997), and space exploration (*Project Orion*, 2002). His most recent book is *Turing's Cathedral: The Origins of the Digital Universe* (2012). He is now working on a book about the beyond-digital world.

Keller Easterling (US) is an architect, writer and professor at Yale University. Her books include *Enduring Innocence: Global Architecture and its Political Masquerades* (2007), and *Organization Space: Landscapes, Highways and Houses* *in America* (2001). A forthcoming book, *Extrastatecraft: Infrastructure Space and Political Arts*, examines global infrastructure networks as a medium of polity.

Félicie d'Estienne d'Orves (FR) works with new technologies, light and sculpture to create a contemporary form of kinetic art. She uses her audiovisual installations to research the process of vision and its conditioning.

Raviv Ganchrow's (US/NL) work focuses on interrelations between sound and space, aspects of which are explored through sound installations, writing and the development of acoustic-forming and vibration-sensing technologies. He is currently a faculty member at the Institute of Sonology, The Hague.

HC Gilje (NO) works with real-time environments, installations, live performance, set design and single channel video. For the past five years he has focused on animated light and shadows, projected light objects and projected light spaces.

Carl Michael von Hausswolff (SE) is a composer and conceptual artist. As a composer he uses recording as his main instrument. As a conceptual artist he works with performance art, light and sound installations and photography.

Simon Ings (UK) is a novelist. He edits *Arc*, a magazine of futures and fiction from the makers of *New Scientist*, and is working on a history of science under Stalin.

François Laruelle (FR) is a philosopher. He is noted for developing a science of philosophy he calls non-philosophy.

Roger F. Malina (US) is an astronomer and editor. He is a Distinguished Professor of Art and Technology at the University of Texas, Dallas, where he is developing Art-Science R&D and Experimental Publishing research. He is former Director of the Observatoire Astronomique de Marseille-Provence. He has also been involved for 25 years with the Leonardo organisation, whose mission is to promote and make visible works that explore the interactions between art, science and new technologies.

Geoff Manaugh (US) is a Los Angeles-based writer who provides illustrated architectural news and conjecture on his well-known BLDGBLOG. He is a former senior editor at *Dwell* magazine, a contributing editor to *Wired* UK, and author of the *BLDBLOG book* (2009).

Matthijs Munnik's (NL) performances and installations play with visitors' perceptions. He researches all kinds of colour combinations, patterns, and rhythms to create spectacular visual effects.

David P.D. Munns (US) is a historian of science and technology. He graduated with a Ph.D. from Johns Hopkins University in 2003, and has taught history, and the history of science and technology at the Imperial College in London and now at the City University of New York. MIT Press recently published his first book, *A Single Sky: How an International Community Forged the Science of Radio Astronomy* (2012). He is currently finishing another book on the science of the biological effects of climate change.

Omar Muñoz-Cremers (NL) is a writer of many essays and articles on the interfaces between science fiction, music, new media, fashion, football and sociology.

Andrew Pickering (UK) taught for many years at the University of Illinois at Urbana-Champaign; he is now Professor of Sociology and Philosophy at the University of Exeter. His field is science and technology studies, and his books include *Constructing Quarks: A Sociological History of Particle Physics* (1984); *The Mangle of Practice:*

Time, Agency and Science (1995); and most recently, *The Cybernetic Brain: Sketches of Another Future* (2010). His current research explores questions of agency and emergence in art and environmental management.

Gert-Jan Prins (NL) focuses on the sonic and musical qualities of electronic noise and investigates its relationship with the visual. He developed the Synchronator device with Bas van Koolwijk.

Brigitte van der Sande (NL) is an art historian, writer and independent curator.

Saskia Sassen (US) is Professor of Sociology, Columbia University. Among her many books, translated into over twenty languages, are *Territory, Authority, Rights* (2008), and *The Global City* (2001). The recipient of multiple doctor honoris causa and other awards, she was selected as one of *Foreign Policy*'s 100 Top Global Thinkers of 2011.

Yolanda Uriz Elizalde (ES/NL) studied music and recently completed her Master's at ArtScience, The Hague. Her work, both solo and in collaboration, ranges from experimental music to installations.

Willem van Weelden (NL) is an independent researcher and writer. He teaches at the Rietveld Academy in Amsterdam, the Netherlands.

Lebbeus Woods (US, 1940–2012) was an architect. His explorations often dealt with the design of systems in crisis.

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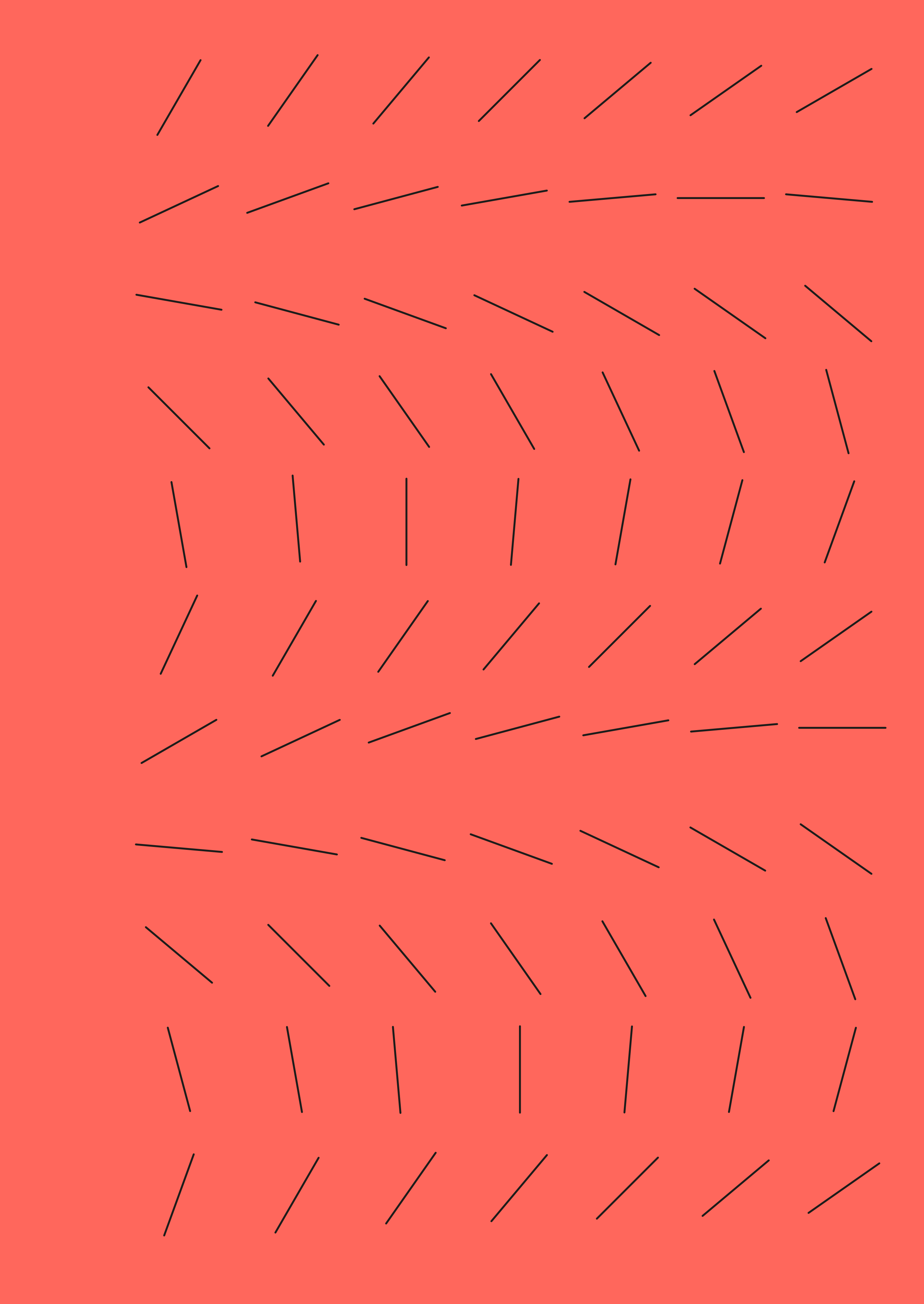

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