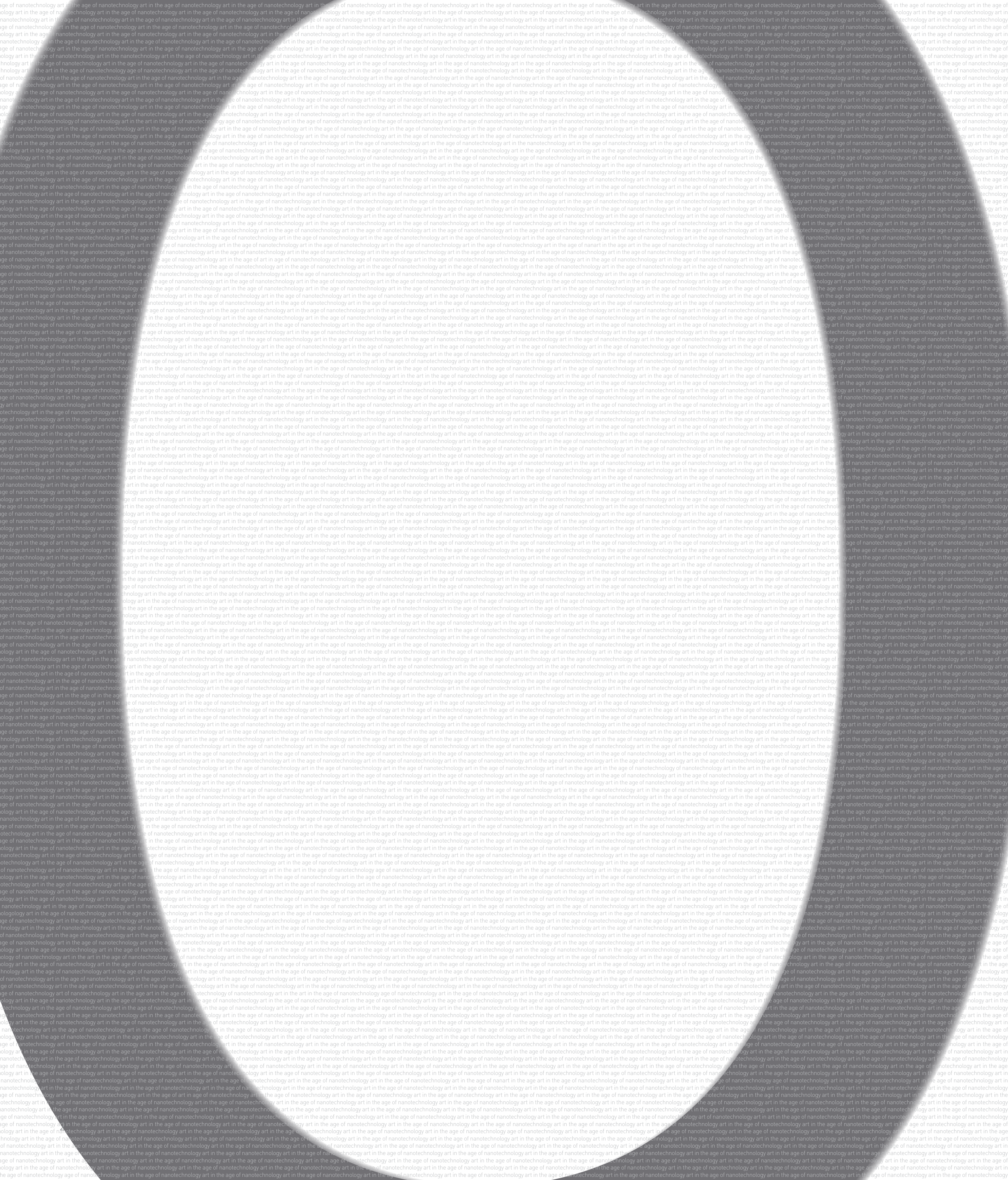

art in the age of nanotechnology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We are about to be able to build things that work on the smallest possible length scales, atom by atom, with the ultimate level of finesse. These little nano things and the technology that assembles and manipulates them, what we call nanotechnology, will, I am certain, revolutionize our industries and our lives....

Richard Smalley, Professor of Physics and Chemistry, Rice University, Houston Texas (106th Congress House Hearings; 1999)

foreword **Professor Jeanette Hacket**, Vice-Chancellor, Curtin University of Technology

Curtin University of Technology is proud to present *art in the age of nanotechnology*. One of the roles of the John Curtin Gallery is to provide a public forum for discourse, where artists can interrogate issues that affect society in new and interesting ways.

art in the age of nanotechnology is a timely exhibition as nanotechnology is very much at the forefront of current research globally. The exhibition also reflects the innovative research and interdisciplinary collaborations that are flourishing here at Curtin.

Collaborations of this nature are often delivered in the form of campus partnerships and developed in conjunction with the Gallery's exhibition program. With *art in the age of nanotechnology* the relationships between the Gallery, the presenting artists and other areas of the University are demonstrably real and highlight the outstanding results that such collaborative approaches can yield for both partners.

art in the age of nanotechnology comprises of five exemplary projects from around the world that showcase the spirit of collaboration between art and science. Through its exhibition program the John Curtin Gallery continues to demonstrate its effectiveness in communicating the cultural strengths of the University through innovative programming and exhibition development.

I would like to welcome our international visitors for this exhibition and its symposium: Boo Chapple, Laurent Mignonneau, Colin Milburn, Mike Phillips and Christa Sommerer.

A project like this relies on the work of many people and I would like to particularly acknowledge John Curtin Gallery program sponsor Navitas; as well as Linda Kristjanson, DVC Research and Development; Mark Woffenden, Founding Director of Curtin's newly opened Resource and Chemistry Precinct; and staff from the Department of Chemistry, especially Eric Bakker, Director of the Nanotechnology Research Institute all for their commitment to this project.

My sincere thanks go to Director, Chris Malcolm and the dedicated staff of the John Curtin Gallery.

Victoria Vesna, James Gimzewski and Tibetan Buddhist monks from the Gaden Lhopa Khangsten monastery, ***Nanomandala***, 2003, installation detail, image courtesy of the Artist

art in the age of nanotechnology **Chris Malcolm**, Director, John Curtin Gallery

art in the age of nanotechnology brings together five projects that all have direct connection to the relatively young and already diverse field of science known as nanotechnology.

Firstly, it will be useful to clarify the most obvious aspect of nanotechnology that fuels popular intrigue – that of scale. With potential for the assembly of materials, structures and machines on a molecular level to completely transform much of our daily lives, concerns are emerging about issues of safety and control. Public debate about nanotechnology and the development and implementation of nano-scale materials is very much alive and there are emerging fears in the sphere of public health.

Nanotechnology operates on a physical scale that is understandably challenging to comprehend. I vividly recall being transfixed in the early 1980s as celebrated astronomer Carl Sagan described a very large number known as a googolplex in his popular television series *Cosmos: a Personal Voyage*[1]. In his striking visual manner, he explained how this number was so incredibly large that should one attempt to actually write it down there was not enough room in the observable universe to contain enough paper to do so. This perplexing notion that a number consisting of a 1 and 10 to the power of 100 zeros would be so vast that it was demonstrably larger than the universe itself was so beguiling that it has stayed with me since. It is now with similar incredulity that I confront the notions of the infinitesimally small in contemplating what is happening within the realms of nanotechnology.

When the term nanotechnology is used it is generally accepted to refer to science dealing with materials up to a maximum size of 100 nanometres. By definition one nanometer equals one billionth of a metre or a more graphic example – and again in the spirit of Carl Sagan – would be the popular comparison that a nanometer is to a metre what a marble is to the planet earth. The actual term nanotechnology was first used by Japanese Scientist Norio Taniguchi in 1974 although the concept had previously been described (but unnamed) in 1959 by renowned physicist Richard Feynman. Throughout the 1980s the notion of nanoscale science was further explored by Eric Drexler who through several key publications helped to define what has become our currently accepted understanding of nanotechnology.

The last century was abound with profound developments in theoretical physics. It is only in recent decades that these developments have been supported by the means to *see* what has been contemplated and described for almost a century. With the advent of hyperfine detection systems like sophisticated particle accelerators, scientists have glimpsed traces of the smallest particles of matter on sub-atomic levels but these still do not allow us to *see*. Exercising control over matter at anywhere near this scale is virtually unimaginable.

One only need consider the unprecedented engineering required to reveal these quantum materials as in the recently commissioned Hadron Collider in Switzerland to appreciate the complexities.

Admittedly this *vision* of the previously invisible has usually been mediated by data rather than perceived optically because of diffraction problems and the wavelengths of light being larger than the objects to be observed but nanotechnology may even be providing the means to develop the near field optical tools to see at these small scales.

Artists have always thirsted for new means of expression and communication. The research and tools of nanotechnology have become fertile ground for artists wishing to create new pathways to the previously invisible layers of our material existence and make links with fundamental aspects of our being through more human sensory aspects like sight and touch.

The works in *art in the age of nanotechnology* are a small glimpse of what is currently being explored and I am very pleased to be able to present the exhibition here at the John Curtin Gallery at a time when Curtin is forging ahead with research in this area with renewed vigour.

art in the age of nanotechnology is presented with the generous support of Navitas and produced in association with Curtin University's recently opened Resource and Chemistry Precinct, the Nanotechnology Research Institute and Centre for Research into Art, Science & Humanity.

NOTES:

1. *Cosmos: A Personal Voyage* is a thirteen-part television series written by Carl Sagan, Ann Druyan, and Steven Soter, with Sagan as global presenter. It covered a wide range of scientific subjects including the origin of life and a perspective of our place in the universe. The series was first broadcast by the Public Broadcasting Service in 1980, and was the most widely watched series in the history of American public television until *The Civil War* (1990). As of 2009, it is still the most widely watched PBS series in the world.

Tactical Atomism

Colin Milburn, Associate Professor of English, University of California, Davis

To begin, as it were, at the beginning of things – which is to say, at the bottom – let us posit three orders of atomism.

Epic Atomism

The first order of atomism belongs to the category of *epic*. This order appears quite early in the cultural record – it corresponds to the atomistic thought of antiquity, the teachings of Leucippus and Democritus, the particulate discourse of early Hindu philosophy – but it is not for reasons of chronology alone that epic atomism is associated with *absolute distance*. Epic atomism describes the elemental composition of matter in the language of archaeology, legend, and myth. Within the order of epic atomism, the indivisible, elementary particles at the base of everyday matter are fundamentally inaccessible, beyond presence. Rather, atoms become thinkable only through a retrospective narration, a philosophical recounting of events temporally and spatially removed from any living witness. Such epic narration reveals our world to be the aftermath of a vast saga of atomic movements, accretions, combinations, and collisions. But this atomic saga is eternally walled off from our world, our human present, separated by insurmountable barriers of scale.

Consider Lucretius's *De Rerum Natura* (*On the Nature of Things*, c. 50 BCE) as the paradigmatic expression of epic atomism. Lucretius suggests that whatever might appear to us as stable matter – the presence and durability of physical things in our world – only does so because of our sheer distance from the atomic movements at the deep structure of nature, the 'first things' at the origin of all material forms:

> For all the nature of first things lies far away from our senses beneath their ken; and therefore since they are themselves beyond what you can see, they must withdraw from sight their motion as well; and the more so that the things which we can see, do yet often conceal their motions when a great distance off... Again when mighty legions fill with their movements all parts of the plains waging the mimicry of war, the glitter then lifts itself up to the sky, and the whole earth round gleams with brass and beneath a noise is raised by the mighty trampling of men and the mountains stricken by the shouting reecho the voices to the stars of heaven, and horsemen fly about and suddenly wheeling scour across the middle of the plains, shaking them with the vehemence of their charge. And yet there is some spot on the high hills, seen from which they appear to stand still and to rest on the plains as a bright spot.[1]

Comparing our observation of everyday matter to the position of a distant hillside spectator staring down on inscrutable military actions, Lucretius here begins to articulate the epic nature of classical atomism. For in the same way that literary epics such as the *Illiad* or the *Aeneid* depict the heroic military struggles of the ancient past as distinctly separated from the present world, Lucretius asserts that what we observe as gross matter is itself the legacy of old battles between legions of atoms in the void, massive military conflicts of infinitesimal soldiers taking place beyond the limits of our perception, stretching back to the dawn of time:

> Of this truth, which I am telling, we have a representation and picture always going on before our eyes and present to us: observe whenever the rays are let in and pour the sunlight through the dark chambers of houses: you will see many minute bodies in many ways through the apparent void mingle in the midst of the light of the rays, and as in never-ending conflict skirmish and give battle combating in troops and never halting, driven about in frequent meetings and partings; so that you may guess from this, what it is for first-beginnings of things to be ever tossing about in the great void...[S]uch tumblings imply that motions also of matter latent and unseen are at the bottom. For you will observe many things there impelled by unseen blows to change their course and driven back to return the way they came, now this way, now that way in all directions round. All, you are to know, derive this restlessness from the first-beginnings.[2]

In the agitation of dust motes, philosophical reason enables us to discern traces of deep history, first-beginnings, the mythic realm of epic atomism: the "motions…of matter latent and unseen [that] are at the bottom". And at the bottom of things (an essential trope for this and subsequent orders of atomism), we find *martial law* – the politics of nature itself. But the human world has no ability to engage in this martial law, we cannot intervene or change its operations. We can only accept the inevitable, tragic, consequences of the atomic epic that renders the whole world perpetually under siege:

> With good reason therefore all things perish, when they have been rarefied by the ebb of particles and succumb to blows from without...and bodies [of matter] never cease to destroy a thing by thumping it from without and to overpower it by aggressive blows. In this way then the walls too of the great world around shall be stormed and fall to decay and crumbling ruin.[3]

Hence, the Greeks' siege of Troy, the military clash of Rama and Ravana, Grendel's massacre of Hroðgar's mead hall, Roland's battle at Roncesvalles, the Niebelungs' last stand in Etzel's hall – indeed, the entire epic tradition of world literature – would thus seem analogous, in terms of narrative architectonics, to the ongoing but absolutely distant atomic processes of the universe. As Mikhail Bakhtin has written:

> Thanks to this epic distance, which excludes any possibility of activity and change, the epic world achieves a radical degree of completedness...The epic world is constructed in the zone of an absolutely distanced image, beyond the sphere of possible contact with the developing, incomplete, and therefore re-thinking and re-evaluating present.[4]

Epic atomism has never disappeared; to be sure, its resurgence in the seventeenth century, for example, in the work of Thomas Hobbes, René Descartes, and Robert Boyle, played a significant role in the history of modern science and modern political theory, and even today we continue to see epic atomism used as a rhetorical form in popular science writing and science textbooks. But by the eighteenth century, a different order of atomism had ascended.

Strategic Atomism

The second order of atomism belongs to the category of *strategy*. Coterminous with the age of chemistry, especially in the wake of Dalton's atomic theory, strategic atomism is characterized by the mass mobilization of atoms and molecules as ensembles or aggregates, in real time, towards a specific objective. This order of atomism underwrites the production of the chemical formula and the reaction mechanism – the abstract diagrams describing various surges and collisions of mobile atomic troops, the coordinated evolution of stable products out of measured reactants. The strategic aspect of the chemical formula manifests, initially, in its predictive linearity, its status as the plan or map for an extensive campaign in the space of elemental reactivity, involving the decisive gathering and deployment of billions upon billions of agitated atomic entities. While these entities may be abstractly conceived as individuals – atomically indivisible, discrete units – they are nevertheless only approachable in the vague form of the multitude, a statistical calculation. Let us not forget the monumental status of Avogadro's number ($\sim 6.02 \times 10^{23}$) in the historical development of chemical equations, and the correspondingly gigantic legions deployed in real laboratory operations, where even smallest drop of volatile substance represents an entire populace.

To be sure, the militarized rhetoric of epic atomism also informs the order of strategic atomism, for instance, in the terminology of certain chemical reactions: the *nucleophilic* *attack mechanism*, the *electrophilic attack mechanism*, the *backside attack*, and so forth. But where epic atomism postulated such elemental battles retrospectively, from the vantage point of metaphysical distance and the language of ancient history or mythology, strategic atomism instead coordinates these attacks prospectively, arranging the theatre of chemical warfare through various apparatuses (beakers, flasks, test tubes, titration devices, coils, Bunsen burners, graduated cylinders, combustion chambers, centrifuges, and such), activating and controlling the mass movements of combatants within that modifiable scientific battlespace.

Let us consider Jean Perrin's *Les Atomes* (*Atoms*, 1913) as a paradigmatic expression of strategic atomism. Addressing the skepticism then still lingering within certain scientific circles, as well as the broader public, about the actual existence of atoms (that is, atoms as material entities rather than metaphysical ideals or heuristic fictions), Perrin argues that adoption of the atomic hypothesis effectively turns chemistry from guesswork to strategy, enabling scientists to objectively describe and then anticipate, enact, and launch specified chemical reactions. For this reason, Perrin writes, we finally give "capital importance to molecular theories in the coordination and prediction of chemical phenomena".[5] It is a strategic practice of coordination and prediction, indeed, that persistently resonates with the logic of military strategy, such as when Perrin describes laboratory experiments on monatomic gasses as analogous to naval battles, with each atom in the system imagined like a warship:

> [T]he material part of the atom is probably enclosed within a sphere, of extremely small diameter, which repels with great violence all other atoms that approach within a certain limiting distance...In the same way, the range of the guns on a battleship very greatly exceeds the circumference of the ship itself. This minimum distance is the radius of a *sphere of protection* which is concentric to the atom and vastly greater than it. We shall find that an altogether new phenomenon is produced when we succeed in increasing greatly the speeds that precede impact, and that then the atoms pierce the protecting spheres instead of rebounding from them.[6]

Working with atoms, then, from the perspective of classical chemistry and physics, may resemble the planning and conduct of maritime campaigns, the movement and disposition of immense atomic fleets by the scientific commander operating from the top down, from the secure distance of experimental control. If the order of strategic atomism finds its confirmation in the abstraction of general chemical formulae from operations carried out in the laboratory, it likewise finds its strategic application in the scalability of these formulae – hence, the order of strategic atomism is the condition of both modern industrial chemistry and modern chemical warfare, not to mention the various projects and aspirations of nuclear power. The era of top-down molecular sciences, which is to say, the era of modern atomism is marked fundamentally by a strategic imaginary that is ultimately political, a conceptualization of masses of microscopic entities ready and available for deployment, drafted into nationalist or commercial enterprises of many different kinds, in many different places. As Michel de Certeau has written:

> In sum, strategies are actions which, thanks to the establishment of a place of power (the property of a proper), elaborate theoretical places (systems and totalizing discourses) capable of articulating an ensemble of physical places in which forces are distributed…The model was military before it was 'scientific'.[7]

Tactical Atomism

The third order of atomism belongs to the category of *tactics*. Tactical atomism emerges within the era of nanotechnology and the historic convergence of allied sciences at the nanoscale, the size regime pertaining to individual atoms and molecules. Where epic atomism typically adopts the retrospective position of chronicle or history, and where strategic atomism typically adopts the prospective position of managerial command or top-down coordination, tactical atomism instead adopts the local position of inhabitation, temporal immediacy, and bottom-up precision. Rather than mobilizing massive forces or predicting formulaic outcomes, tactical atomism engages in the maneuvering of specific units, operationalizing or functionalizing local properties and local structures, taking advantage of the unique physics of matter at the nanoscale, which often differs radically from what we are familiar with at larger scales. Focusing on small numbers of atoms and their repositioning within limited spatial and temporal boundaries, tactical atomism instantiates the art of ordering and arranging (which is, after all, the very definition of tactics) at the bottom of things, the deep structure of matter.

The research field of nanotechnology linguistically registers its relation to the order of tactical atomism, for example, in its aspirations toward *eutactic engineering*: the precise manufacture of systems and materials with optimally designed and well ordered molecular structures.[8] At the same time, the tactical aspect of nanotechnology appears in the ubiquitous tropology of *touch* that has profoundly informed nanoscience from its earliest days.[9] The shared conceptual roots of *tactic* and *tactile*, order and proximity, syntax and touch – etymologically deriving from the Indo-European *tag* (contact) – reappear over and again in nanotechnology's rhetoric of precision engineering through a new *intimacy* with matter.[10] Such molecular intimacy would seem incarnated in the celebrated instrumentation of nanoscale science, for example, the scanning tunneling microscope (STM) and the atomic force microscope (AFM), whose ability to visualize atomic features is a function of the physical proximity of the probe tip to the sample, and whose ability to discretely manipulate and reorder infinitesimal structures depends on direct, local contact between instrument and atom – in other words, a tactical tactility.

Consider Richard Feynman's 1959 speech, *There's Plenty of Room at the Bottom*, as the paradigmatic expression of tactical atomism. Feynman's talk has often been taken as the historical origin of nanotechnology. But despite its visionary qualities, the text has none of the epic grandeur of Lucretius or the strategic ambitions of Perrin. On the contrary, Feynman's occasional piece, put together as an after-dinner amusement for the annual meeting of the American Physical Society at the California Institute of Technology, is characterized throughout by Feynman's famous irony and wit: his overarching attitude that science, for all its seriousness and its strategic values, is also a deeply humanizing endeavor, and an occasion for pleasure.[11] And so, his vision of the future of tactical atomism, bold as it may be, is also facetious, and humble, obeying the laws of physics even as it takes wry jabs at earlier orders of atomism:

> I am not afraid to consider the final question as to whether, ultimately – in the great future – we can arrange the atoms the way we want; the very *atoms*, all the way down!...When we get to the very, very small world – say circuits of seven atoms – we have a lot of new things that would happen that represent completely new opportunities for design. Atoms on a small scale behave like *nothing* on a large scale, for they satisfy the laws of quantum mechanics. So, as we go down and fiddle around with the atoms down there, we are working with different laws, and we can expect to do different things. We can manufacture in different ways…The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big.[12]

Achieving this kind of tactical arrangement of atoms, however, could potentially undermine the order of strategic atomism – indeed, as Feynman jokes, it might very well put traditional chemistry of out of a job:

> Ultimately, we can do chemical synthesis. A chemist comes to us and says, "Look, I want a molecule that has the atoms arranged thus and so; make me that molecule". The chemist does a mysterious thing when he wants to make a molecule. He sees that it has got that ring, so he mixes this and that, and he shakes it, and he fiddles around. And, at the end of a difficult process, he usually does succeed in synthesizing what he wants...But it is interesting that it would be, in principle, possible (I think) for a physicist to synthesize any chemical substance that the chemist writes down. Give the orders and the physicist synthesizes it. How? Put the atoms down where the chemist says, and so you make the substance. The problems of chemistry and biology can be greatly helped if our ability to see what we are doing, and to do things on an atomic level, is ultimately developed – a development which I think cannot be avoided.[13]

And yet, for all that, Feynman also repeatedly reminds that these dreams of atomic manipulation may just turn out to "really be useless".[14] For every aside he makes about the possibility of larger social, political, or economic strategies – glimmers of the global nanotech frenzy that we know today, yet inconceivable in 1959 – Feynman also suggests that the real potentials of tactical atomism may not readily lend themselves to any meaningful strategy. Instead, tactical atomism, as Feynman begins to articulate it, may find its application only as an anti-strategy, a local disruption of serious science or industrial ambition. It may, in the end, simply be a provocation, a laugh, an opportunity for irreverent play:

> Now, you might say, "Who should do this and why should they do it?" Well, I pointed out a few of the economic applications, but I know that the reason that you would do it might be just for fun. But have some fun![15]

Blue Period

We are now, at last, in a position to understand the work of art in the age of nanotechnology. For tactical atomism addresses not only the extent to which the meticulous operations of nanoscience are always already tactical, to some appreciable degree, but also the corresponding collapse between the domain of art and the domain of science entailed by such precision engagements with atomized materiality. To be sure, several nanotechnologists have promoted various technical images made in their laboratories as instances of artistic production, as much as scientific representation. Don Eigler, James Gimzewski, Wolfgang Heckl, Eric Heller, and a number of others now frequently exhibit their images of atomic structures or quantum phenomena in art galleries, compete in artistic competitions, and sell prints for display in the homes of connoisseurs. At the same time, many professional artists and media practitioners have turned to the themes and techniques of nanoscience, frequently collaborating with professional scientists on projects of mutual interest.[16] As Lorraine Daston and Peter Galison have argued, we are witnessing a historic shift in the relationship of scientific images to older epistemic values of mechanical objectivity, truth-to-nature, and trained judgment in the moment of nanotechnology, precisely because nano images render indistinct the formerly distinguishable concepts of nature and artifact, representation and presentation, making and making up – necessitating a new term like *nanofacture* to describe the fabrication of nano images:

> Nanotechnology is manipulation of quite a different kind – intervention by the scientist, through the image, to make things, to cut, move, combine, weld, or set in operation...Now, as images become part toolkit and part art, what are they? Nanofacturers use them as aesthetic objects, as marketing tags, all the while reaching through them to create and manipulate a brave new world of atom-sized objects. The scientific image begins to shed its representational aspect altogether as it takes on the power to build.[17]

Building from the bottom up rather than representing from the top down, operating with images produced in real time through local contact rather than abstract distance or symbolic extraction, the atomistic work of nanofacture is both a seeing and a making, a conjoining of the functions of episteme, techne, and poiesis.[18] This does not mean that nanoart and nanoscience are just the same thing, or behave in the same way. But such tactical nanofacture readily becomes an occasion for negotiating and reworking the cultural boundaries between art and science, emerging sometimes

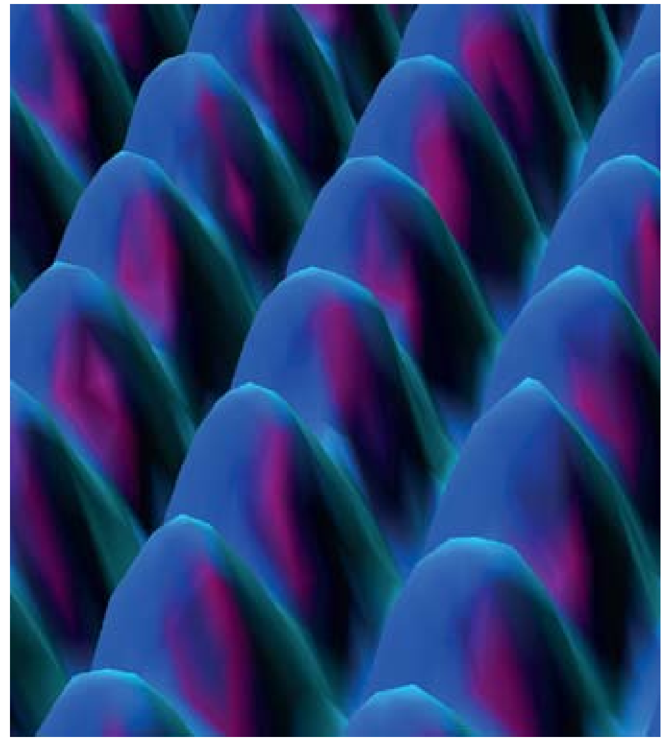


figure 1: Don Eigler, ***Blue Nickel***, image originally created by IBM Corporation

figure 2: Don Eigler, ***Blue Platinum,*** image originally created by IBM Corporation

in the form of critical disruption or even parody, drawing attention to dominant cultural logics and values that shape the work of art alongside the work of nanotechnology.

For example, in the online STM Image Gallery of the IBM Almaden Research Center, Don Eigler and his colleagues showcase several of their most famous images of atomic manipulation, quantum corrals, and 'molecular graffiti' by inhabiting a mock discourse of art history. Describing themselves in the third person as 'the artists', Eigler and his collaborators borrow clichés and common tropes from both art history and quantum physics to provoke an active questioning of the social separation of the objective from the subjective, the aesthetic from the technological. The STM Image Gallery is set up to resemble an art gallery, with different rooms of the exhibition corresponding to different periods of the artists' careers. One room, dubbed 'the blue period', features a set of Eigler's work on the periodicity of metal surfaces. Describing his piece *Blue Nickel* (figure 1), Eigler writes:

> Uninterrupted periodicities can be visually exciting. Consider the tessellations created by the Moors or those of Escher. But for an unreconstructed fcc (110) surface, the rectangular surface unit cell is just plain boring. This boredom launched the artist into his 'blue period', a time during which he found relief by turning the blue-knob-thing on the computer.[19]

With tongue firmly in cheek, Eigler adopts several familiar cultural positions at once: the artist obsessed for a time with a single color (Picasso); the art historian who might attach an overwrought sense of melancholy to the artist's blue period, *feeling blue* equated with *painting blue*; and also the irreverent scientist who produces art simply by playing idly with his scientific instrument, as if exposing the non-labor of the so-called 'work' of art. But if thereby appearing to lampoon of the institutions of high art, or at least their rhetorical apparatuses, Eigler's work from his blue period also lampoons the institutions of technoscience, sardonically addressing the mundane labor conditions and the economic realities involved in the generation of nano knowledge, as much as nano aesthetics.

For the *uninterrupted periodicity* described here, the repetitive *boredom* inscribed under the sign of 'the blue period', must be understood in relation to the material conditions of technical and artistic labor in which these images have been produced: namely, the laboratories of IBM – *Big Blue* itself – and the fact the Eigler's career in nanotechnology first soared into international prominence thanks to his virtuoso production of the IBM logo out of xenon atoms on a nickel surface. Dubbed *The Beginning* in the STM Image Gallery, this particular image (whose xenon atoms have been colored blue) features the following caption:

> Artists have almost always needed the support of patrons (scientists too!). Here, the artist, shortly after discovering how to move atoms with the STM, found a way to give something back to the corporation which gave him a job when he needed one and provided him with the tools he needed in order to be successful.[20]

Indeed, the STM Image Gallery as a whole is an active recollection of the fact that Eigler's entire career has occurred within 'the blue period', employed by the global corporation of International Business Machines – and that he and his colleagues, as the artists/scientists who crafted the aesthetic nanoscale imagery, who developed the technical procedures of 'moving atoms' in this way, and who discovered important principles of nanoscale surface science through their research, do not, after all, control the copyright on their images. As the copyright notices all over the STM Image Gallery remind us, these images must always be credited as "originally created by IBM Corporation".[21]

Eigler's nanoart, progressing from *The Beginning* through *Blue Nickel* and *Blue Platinum* (figure 2), the last of which represents "the epitome of his 'blue period'",[22] suggests the escalation of the surplus value of Eigler's scientific work, a surplus value measured first in the form of common currency and later in precious metal – but to whom, exactly, has the bulk of this surplus value accrued? And what further ventures has it enabled? It seems, indeed, that the exhibition of nano artwork featured in the STM Image Gallery, as much as it might constitute a parodic inhabitation of the pretensions of high art so as to elevate the practical and tactical operations of nanoscience, also comments on the corporatization of scientific knowledge that affects in every way the work of art in the age of nanotechnology.

Nanotechnology of the Commons

So we begin to see how tactical atomism lends itself toward the projects of so-called 'tactical media', even in the institutional space of corporate technoscience. In the expanded sense developed by Rita Raley, "tactical media signifies the intervention and disruption of a dominant semiotic regime, the temporary creation of a situation in which signs, messages, and narratives are set into play and critical thinking becomes possible".[23] As Raley compellingly shows, such tactical media operations necessarily occur inside, not outside, the technocultural forms in which they unfold, as transitory sites of immanent critique, microscopic interruptions:

> Whether oriented toward systempunkt or exploit, tactical media comes so close to its core informational and technological apparatuses that protest in a sense becomes the mirror image of its object, its aesthetic replicatory and reiterative rather than strictly oppositional...[T]actical media's imagination of an outside, a space exterior to neoliberal capitalism, is not spatial but temporal...[T]actical media do not necessarily evade the us-them dialectic, but they do recast it such that 'us' and 'them' are no longer permanently situated.[24]

For example, consider the *Nanobama* project created by John Hart, an assistant professor of mechanical engineering at the University of Michigan. In early November 2008, in the final days of the U.S. presidential race between Barack Obama and John McCain, Hart and his colleagues released a collection of nanotechnology images on the photo-sharing website, *Flickr* (figure 3). Hart also set up an independent website, www.nanobama.com, featuring a smaller selection of the same images. At both locations, the exclamation *Vote for science!* appeared prominently alongside these digital micrographs of teeming 'nanobamas': "Microscopic faces of Barack Obama made using nanotechnology, and imaged using a scanning electron microscope. Each face consists of millions of vertically-aligned carbon nanotubes, grown by a high temperature chemical reaction".[25] The *Nanobama* images began to circulate rapidly around the Internet, published and republished by an astounding number of U.S. and international media outlets, and gaining notoriety that seemed to go beyond their specific relationship to the imminent U.S. election. Indeed, Hart later suggested that the global appeal of the *Nanobama* project probably had more to do with making nanotechnology conceptually accessible than with its overt political content:

> [T]he media attention for the nanobamas got a bit crazy and it kind of overwhelmed me at first. I realize now why it happened the way it did but I really didn't think about what could happen in advance when we made them. But it's exciting because I mean these pictures have now been seen by millions of people. They were literally everywhere for a while, in newspapers and websites around the world, on all continents, popping up in all kinds of places that I'd never expected. And how many people would have ever seen a structure made out of carbon nanotubes?[26]

Thus, as one of many instances of the grassroots, self-organizing efforts of individual citizens to launch innovative, small-tech media in support of the Obama campaign, and simultaneously as an effort to make nanotech knowledge open and accessible to millions of people, the *Nanobama* project is a quintessential instance of tactical atomism. As Raley has indicated, such tactical projects "are not oriented toward the grand, sweeping revolutionary event; rather, they engage in a micropolitics of disruption, intervention, and education".[27] In this way, *Nanobama* connects with politics from the bottom up, redrawing the symbolic field of the political at the atomic level of matter – or rather, vividly attending to the extent to which the atomic level of matter is always politicized under any regime of atomism. By visibly manipulating and re-atomizing (unsedimenting or deterritorializing) the political field through the local instrumentation of nanoscience, *Nanobama* performs a techno-artistic stunt: a playful scientific experiment whose potential for immanent critique stems from its hyperbolized over-identification with the extant mediascape. As such, Hart's opportunistic and quickly executed project – "It took about two days of work"[28] – manages to target not only the recent history of U.S. science policy, but also the broader processes of intellectual commodification at work in today's technoculture.

What does *Vote for science!* mean, particularly in the context of images that foreground their relation to the field of 'nano' as much as their relation to the field of 'Obama' (figure 4)? The suggestion seems, at first glance, animated against the notorious abuses of science that took place under the George W. Bush administration: the ban on federal funding for embryonic stem cell research; the disinformation campaign coordinated against the scientific consensus on climate change; the misrepresentation of research results on abstinence and AIDS; and so on, and so forth.[29] As figured by the *Nanobama* project, Barack Obama would appear the antidote to these abuses of science, while his Republican opponent, John McCain, would seem to represent a continuation of the previous administration's position on science. But although the Bush administration's track record on many scientific issues was undeniably horrific, at the same time, nanotechnology research flourished under Bush-era policies to an exceptional degree. In 2003, for example, President Bush approved the U.S. 21st Century Nanotechnology Research & Development Act, which authorized $3.7 billion (USD) between 2005 and 2008 for the flagship U.S. National Nanotechnology Initiative. So this *Vote for science!* encouraged by the *Nanobama*

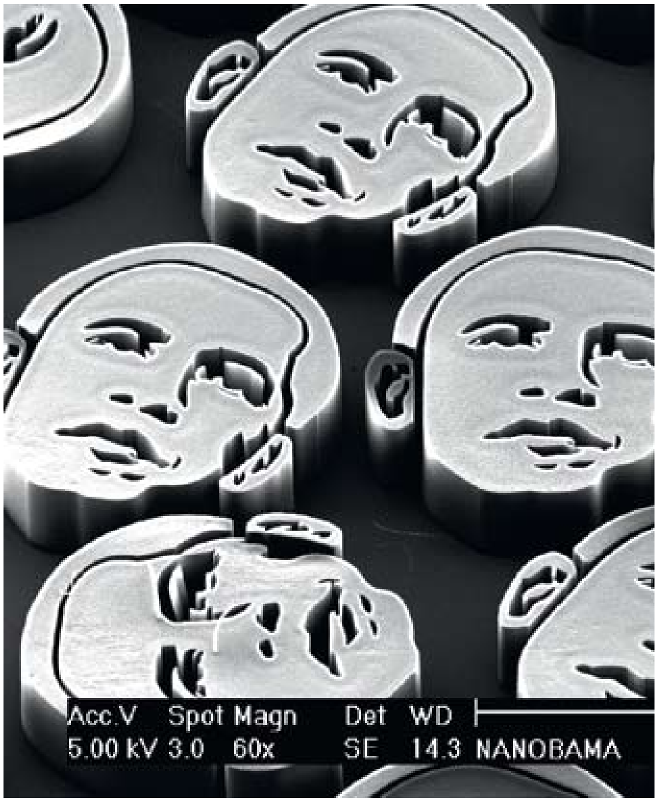


figure 3: John Hart, ***Nanobama***, “NANOBAMA_field1”, reproduced with permission of John Hart

figure 4: John Hart, ***Nanobama***, “NANOBAMA_ncrowd”, reproduced with permission of John Hart

project, to the extent that it relates to the scientific field actually represented in the images themselves – namely, nanotechnology – does not seem a mere complaint about any lack of support for nanoscience under Bush, but more likely speaks to the underlying agendas of those policies that drove nanotechnology to the top of national funding priorities in the early years of the new millennium. Indeed, we might understand *Nanobama* as an appeal to a science in general, and a nanotechnology in particular, whose place in the social order would not be solely determined by its relevance to particular ideological positions and particular economic policies, its relevance to certain social classes or certain regimes of power. After all, Hart has said that he dreams of a nanotechnology “that would affect and benefit all of mankind”.[30] So a ‘vote for science’ would seem to open onto the possibility of *an unincorporated nanotechnology* – or indeed, *a nanotechnology of the commons*.

To be sure, the notion of the commons and the politics of intellectual property saturate the *Nanobama* project to such a degree that it is nearly impossible to see the *Vote for science!* otherwise. Hart has even indicated the amusing way in which *Nanobama* resonates with free culture and creative commons discourses: “Having fun with something like this is important to maintaining a creative culture”.[31] One of the images from the *Nanobama* project, labeled *how they’re made* (figure 5), depicts the technical procedure for creating nanobamas out of carbon nanotubes. As we see in the upper left corner, at the root of the entire project is Shephard Fairey’s *HOPE* poster – a poster that quickly became synonymous with the Obama campaign (even though the campaign never officially claimed any affiliation with Fairey or his work), and is now one of the most iconic and widely-recognized images in contemporary American culture. But Fairey’s poster has also found itself at the center of a heated debate over intellectual property, copyright law, free culture, and guerrilla art.

In the aftermath of the 2008 election, Fairey became engaged in a legal battle with the U.S. Associated Press (AP). The AP discovered that Fairey had based his poster on a photograph shot in 2006 by AP freelance photographer Mannie Garcia. The AP claimed copyright ownership of this photograph, requesting appropriate compensation from Fairey. To make matters more complicated, Garcia has since claimed that he, and not Associate Press, owns the copyright on this disputed photograph. In February 2009, Fairey filed a federal lawsuit against the AP, hoping for a declaratory judgment that his use of the photograph actually falls under the ‘fair use’ doctrine of U.S. copyright law.[32] Despite publicly championing artistic fair use in this way, upholding the rights of street artists like himself to remix and repurpose copyrighted materials,

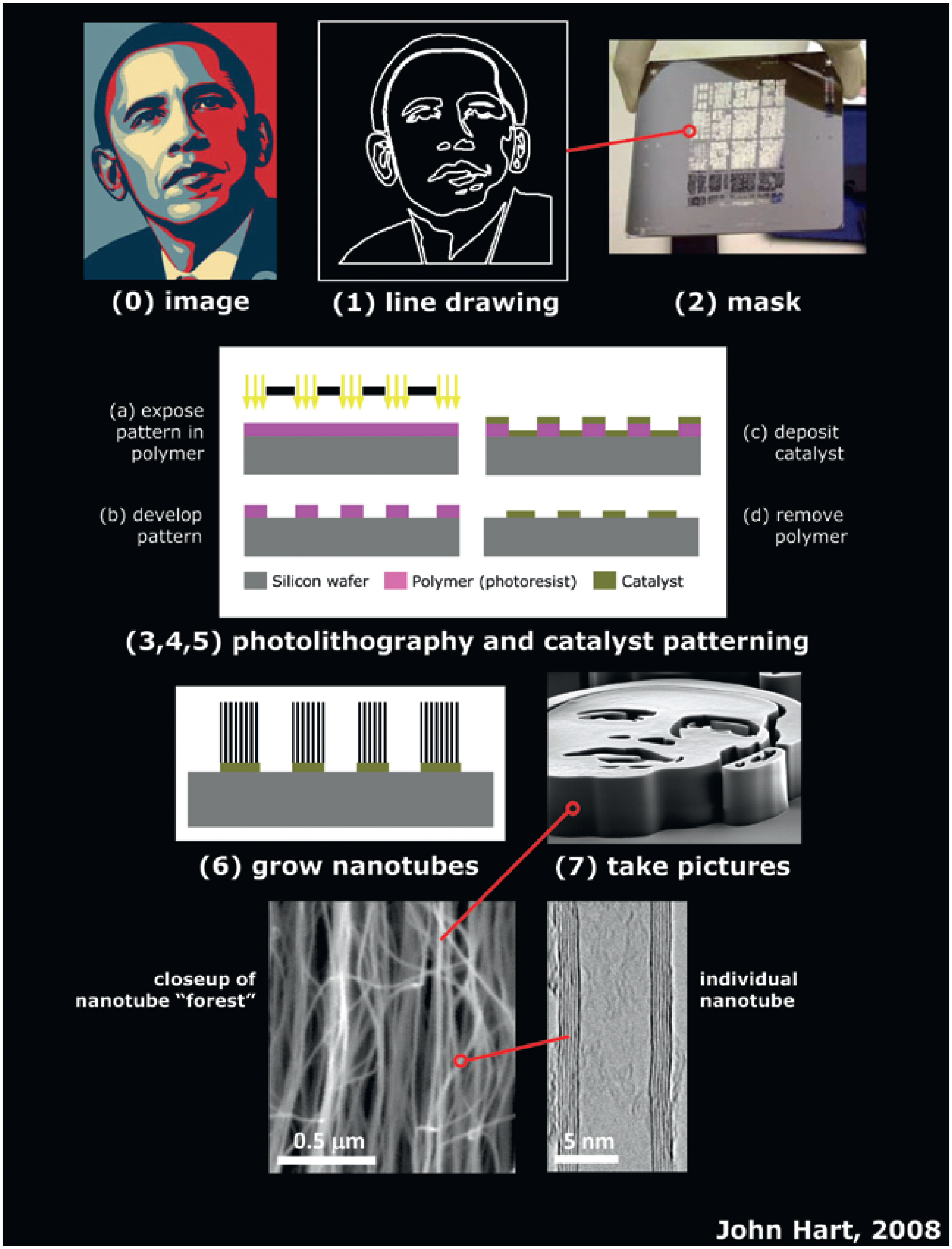


figure 5: John Hart, ***Nanobama,*** "how they're made", reproduced with permission of John Hart

Fairey has been known to vigorously assert intellectual property rights over his own art, for example, threatening legal action against the graphic designer Baxter Orr in 2008, who appropriated and transformed an image from Fairey's street art project *Andre the Giant Has a Posse* (1989) for his own parodic piece called *Protect* (2008).[33] These events immediately generated an intense worldwide flurry of media reports, Internet bloggage, and water-cooler talk about the legal and ethical conditions of art and authorship in today's convergence culture.[34] As Lisa Cartwright and Stephen Mandiberg have argued, however, the vituperative debate surrounding the 'Fairey-AP circus', polarized between the terms of ownership and fair use (which thus already sets the discussion within a certain framework of intellectual property law), effectively covers up the multiple lines of influence, borrowing, repurposing, and transformation actually at work in any instance of cultural production whatsoever.[35]

Nanobama seems to anticipate and directly confront this volatile state of commodity culture, where even guerilla artists might be swift to become zealots for private property. *Nanobama*'s replication of the *HOPE* poster at the nanoscale, the atomistic reconstitution and serial reproduction of the image in a Warhol-esque panoply of Obamas, registers the sense in which Obama himself has become yet another commodity, the sense in which the image of 'HOPE' for a different future has already itself become just another reincarnation of the cultural dominant. Indeed, insofar as the *Nanobama* images were produced through a photolithographic masking technique (figure 5), the very concept of 'mask' now appears over-determined in the historic moment represented by this intersection of Obama, the work of art, and nanotechnology. For the multiplication of Obamas here at the nanoscale, reproduced via high-tech masks that themselves replicate a mass-reproduced and extensively marketed instance of street art (which now, in itself, bodies forth the limits of free culture) would suggest the extent to which Obama is always already multiple Obamas, always already operating as an endless series of masks or simulacra – which is to say, the surplus value of Obama. The surplus of Obama(s) made visible here through the virtuosity of nanoscience, the repetition of infinitesimal structures that would otherwise literally evade human perception, registers the mobilization of many different desires and many different meanings around the figure of Obama...including 'science!' of course, as well as the possibility that any real change or real difference might be well beyond 'hope', especially under the reign of a cultural logic that so thoroughly reproduces itself, over and over again *at every scale*.

The tactical intervention of *Nanobama* does not, then, reside foremost in whatever specific propaganda or political action it may or may not have motivated on the eve of the 2008 U.S. presidential election. As Hart has said: "I really didn't mean it in a political way...It was really for fun".[36] As an exercise in scientific fun, *Nanobama* simply extends and reproduces the same message of hope – a repetition of hope all the way down to the bottom, a surplus of hope – that Obama himself, as the new U.S. president, might rectify the political and scientific policies of the past. But more to the point, as an exercise in scientific fun, *Nanobama* toys with the politicization of nanotechnology by gratuitously nanotechnologizing politics. It becomes a worldwide sensation precisely through its over-identification with the mediascape of technological reproduction that now extends both above and below the human scale, from the global to the molecular. The age of high-tech reproducibility, even in neutralizing the aura of the sacred original, has not opened onto a new common or commons, but instead accelerates an evermore vigilant commodification of all images, all technologies, all molecules.[37] And that is what *Nanobama* shows us, tactically, comically, and atomistically. If it points to a hope beyond hope, it is only in the uncertain future registered in the suggestion to *Vote for science!*: to democratize science, by whatever means available; to galvanize the material common at the bottom of things – the atomic or 'indivisible' common – against molar mechanisms of symbolic capture and dividuation...even those represented today by the politics of liberal democracy itself.[38]

The Midas Touch

Similarly, we might compare the *Midas* project, created by Paul Thomas in 2006. The *Midas* project renders the nanoscale interactions that occur when human skin contacts metallic gold into an interactive media experience, exploring and questioning precisely "what is transferred when gold is being touched".[39] Working with the SymbioticA Lab of the University of Western Australia and the Nanochemistry Research Institute (NRI) of Curtin University of Technology, Thomas employed an atomic force microscope (AFM) with a gold-coated cantilever to produce visual and acoustic images of cultured human skin cells, which were themselves grown on collagen-covered gold substrates. In collaboration with Kevin Raxworthy, who developed the software for the project, the image-data from the gold-cantilever AFM was then mashed up with a genetic algorithm for evolving digital cellular automata – representing self-replicating molecular machines, or *nanobots* (figure 6).

The visual and acoustic data, projected in an installation space, makes the nanoscale interactions between skin and gold perceptible at the scale of the human sensorium. A viewer interacts with the projected data in the installation through a 3D metal cast of a skin cell, plated in 9-karat gold (figure 7). When touched, the resulting electrical circuit triggers a soundscape of the AFM-atomic vibrations, and also launches the genetic algorithm for the cellular automata (the self-replicating nanobots) to interact with the AFM images on display: "The nanobots then grow, feed, breed and die based on [their algorithmic] instructions and the environment [the data-images of the cell] in which they exist. The nanobots gain their energy from eating the red, green and blue colors of the skin cell images, replacing them with the color of gold".[40]

As Thomas explains, the *Midas* project "invites the viewer into a discourse between what constitutes a phenomenological experience of nanotechnology to counter the picture given to us by scientists and writers who generate a textural becoming of the boundaryless humans".[41] The *Midas* project renders palpable the disintegration of corporeal boundaries at the nanoscale, the electronic and atomic exchanges that constitute the zone of touch, the particulate tags or tactile transactions that happen in the interface. By incorporating the viewer into this molecular commons – the atomized zone of metal and flesh held in common – *Midas* creates a temporary, even instantaneous, space of intimacy and embodied practice (a nano-practice of contact), which facilitates critical reflection on the transvaluation of both the human and the atom in the global discourse of nanotechnology. It enables us to question "whether we confront the materialistic values inherent in nanotechnology via developing new products or the interest in seeing the body as servicing the medical industry, or we embrace the deterritorialization of the body in hope of a [more utopian or science-fictional] vision".[42] Indeed, the *Midas* project draws our sensory attention to the deterritorialization of the body through the machinations of nanoscience, and the subsequent reterritorialization of the body by transnational market forces: those forces of the nanotechnology industry represented here in the metaphor of self-organizing nanobots devouring all flesh, turning it into gold (figure 8).

The *Midas* project anticipates the extent to which capital discovers ever more investment opportunities in molecular space – even in molecular gold itself. (Consider the World Gold Council's efforts to build 'trust in gold' during the global market crash through its *utilizegold*™ campaign, which, since May 2008, has been aggressively advertising how unique noble "characteristics make gold an ideal material for such wide-ranging applications [in nanotechnology]"[43]). The consuming nanobots that turn everything into gold (not, of course, an

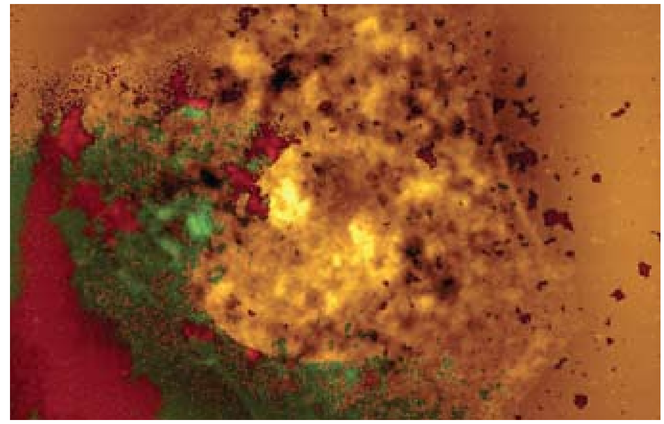


figure 6: Paul Thomas and Kevin Raxworthy, ***Midas***, human skin cell, under siege by "nanobots", AFM image of an epithelial cell, scanned using a gold-coated cantilever, image courtesy of the Artists

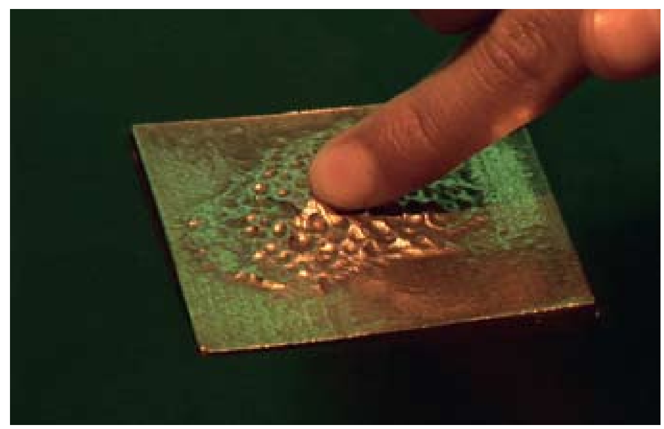
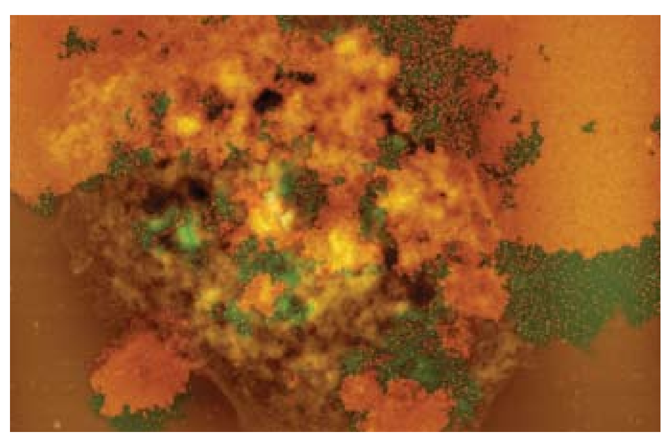


figure 7: Touching the gold–coated metal cast skin cell, from the ***Midas*** installation at the Sk-interfaces exhibition closing event, FACT (Liverpool, 2008), image courtesy of the Artists

figure 8: Paul Thomas and Kevin Raxworthy, ***Midas***, autonomous nanobots converting biomolecules to gold, image courtesy of the Artists



alchemical fantasy of transmutation, but a metaphor for modern capital) instantiate the propertization of molecular structures or cell lines that might otherwise be held in common.[44] But if these nanobots – whose conquest of the cell shockingly recalls the militarized particles of Lucretius, the atomic battleships of Perrin – are to represent something like the production of surplus value from the capture of whole molecular classes, or likewise, any one of the strategies through which biocapital and nanocapital operate today, this image of nanotechnology gobbling up human cells and transforming every last atom into lucre would then seem to indicate a strategy gone haywire, turned against itself, operating autonomously and out of control.

Thomas thus remind us that, in the myth of King Midas, the 'Midas touch' wound up being a curse, a horrific power that turned all human and physical values into meaningless metal – which, in the language of speculative nanotechnology and its notorious scenario of 'grey goo', might be imagined as a kind of 'gold goo'.[45] Revitalizing mythic discourse, tactically opening the absolute distance of epic narration to the concerns of the present, the refiguration of gold goo in the *Midas* project exposes the economic infrastructure of the nanotechnology industry, its mandate to turn tactical atomic technologies into corporate strategies – at any cost.

For comparison, we might take a quick look at the U.K.-headquartered nanotech company, Midatech. Midatech advertises its proprietary development of self-assembling, biocompatible nanoparticles possessing a core of noble metal, such as gold. Thanks to patent recognition in Europe, Australia, and the United States of its single-step process for growing metallo-nanoparticles coated with biochemical ligands – dubbed 'nanocells' – Midatech is now the exclusive world leader in production and application of these synthetic nanocells for pharmaceutical purposes. Commenting in 2008, Tom Rademacher, Chairman of the Midatech Group, said that the transnational patenting of its gold-core nanocells, "represents the cornerstone of Midatech's nanotechnology IP portfolio and positions Midatech as the world leader in the development of nanoparticles for nanomedicine...[The patenting] puts Midatech in an extremely strong position from which to engage in high value international collaborations in order to advance our nanoparticles into the clinic".[46] We see how the strategic language of 'high value' and 'IP portfolios' here completely dominates the ostensible source of value (namely, the practical role of gold nanoparticles in clinical medicine) – that is, how the speculative mechanisms of finance capital are now found as the base of nanomedicine, rather than the other way around.[47]

But this ordering is already suggested in the way the transnational corporation has appropriated the Midas myth. By alluding to the symbolic space of epic atomism and alchemical transmutation in the form of a trademark, capitalizing on the name of Midas and his 'Midas touch', Midatech implies that its own patented gold-core nanocells will turn everything into gold. It will measure (*mida* in Spanish) its technical successes in bullion, both symbolic and real. For those who pay attention to IP portfolios, the presumably ubiquitous deployment of these golden nanocells to "kill cancerous cells and drug-resistant bacteria" all over the world – the spread of the Midas touch – might therefore seem to make for a sound investment.[48] But Midatech has, apparently without any irony, strategically forgotten or misremembered that the Midas story is actually a cautionary tale of gold goo, that Midas is a fable about the danger of lucre catastrophically annihilating the human lifeworld – which is to say, the common.

This strategic forgetting, this erasure of the common under the regime of capital, is made strikingly evident in juxtaposition with Thomas's *Midas* project. For this work of art tactically intercepts the same discursive field mobilized by Midatech, but instead of blinding or misremembering, enables us to *feel* the space of the molecularly unbounded body (the deterritorialized body we inhabit in common) in the process of its recapture by the networks of high-tech industrialism – while at the same time, offering critical resources for beginning to question, and to interrupt, this process from the interior moment of a tactical atomism.

Aftermath

So to end, as it were, not at the top but again at the bottom – which is precisely the point. Orders of atomism ground political orders – and vice versa. But for the lowest level of atomism, the opportunistic, incidental, and local ordering characteristic of tactical atomism, the ground is not fundamentally stable (and there is, after all, plenty of room at the bottom), even if that atomic commons is often temporarily stabilized or captured by operations at a higher order.

Thus the work of tactical atomism, blurring divisions between art and science – and sometimes launched against tactical atomism itself – inhabits and opens internal spaces of immanent critique, aesthetic mutation, or local change (whether on the order of matter, or the order of politics, or both at the same time). In so doing, it touches upon, and rediscovers, the possibility of something like hope...through the blue period, across the absolute distance, and beyond the foreclosure of the common.

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Collaboration between the arts and sciences has the potential to create new knowledge, ideas and processes beneficial to both fields. Artists and scientists approach creativity, exploration and research in different ways and from different perspectives; when working together they open up new ways of seeing, experiencing and interpreting the world around us.

(Australian Network for Art and Technology; www.synapse.net.au; accessed 11/01/2010)

Nano_essence 2009 **Paul Thomas and Kevin Raxworthy**

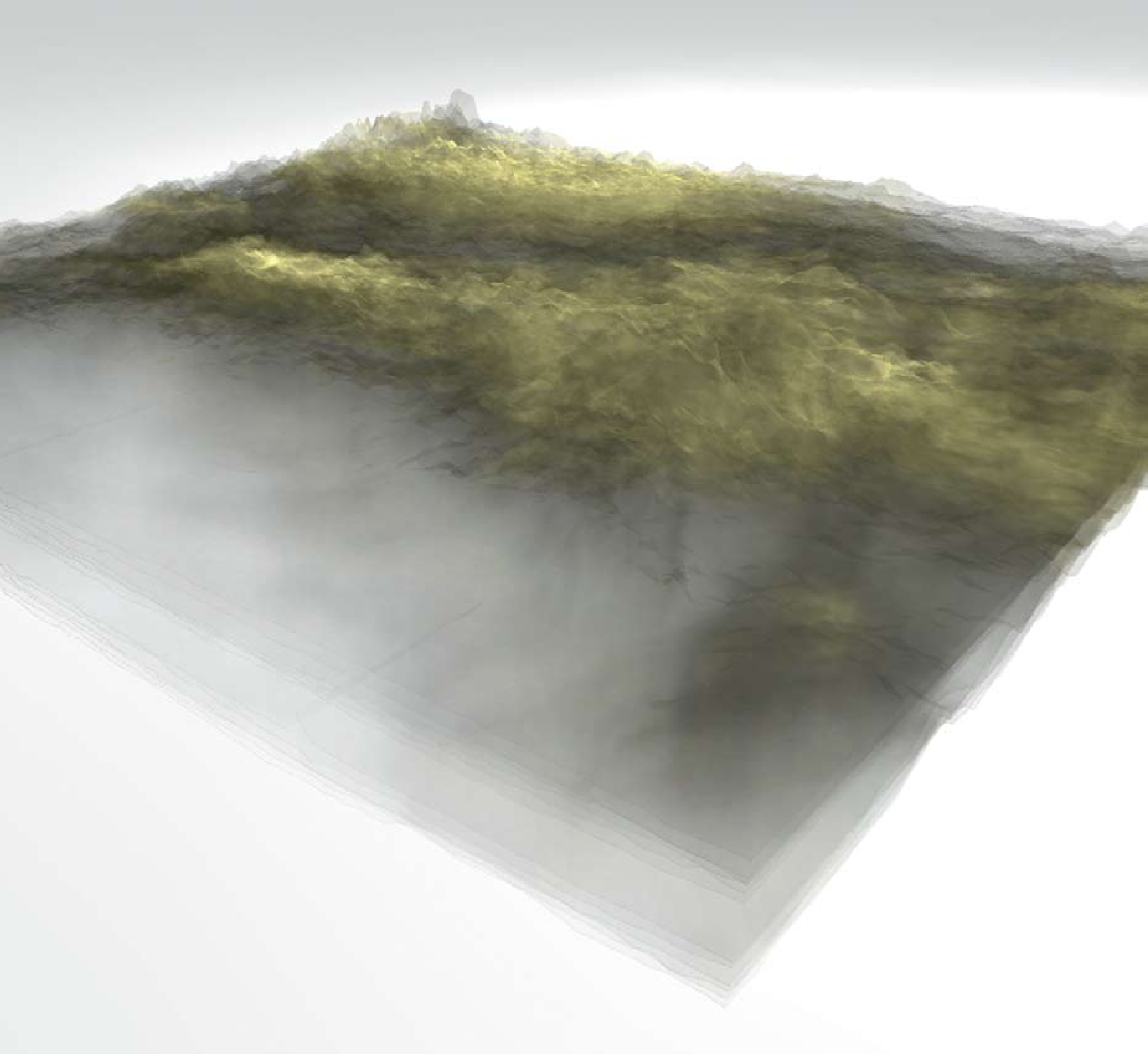
In ***Nano_essence*** a single skin cell is analysed with an Atomic Force Microscope (AFM) to explore comparisons between, life and death at a nano level. The humanistic discourse concerning life is now being challenged by nanotechnological research that brings into question the concepts of what constitutes living.

The space of the body can be seen at an atomic level as having no defining boundaries. The proposal for nanotechnology to reshape nature, atom by atom, develops an interesting debate as to the constitution of life. The *Nano_essence* project aims to construct a physical experience to examine a spatial envelope between the scientific and metaphysical world.

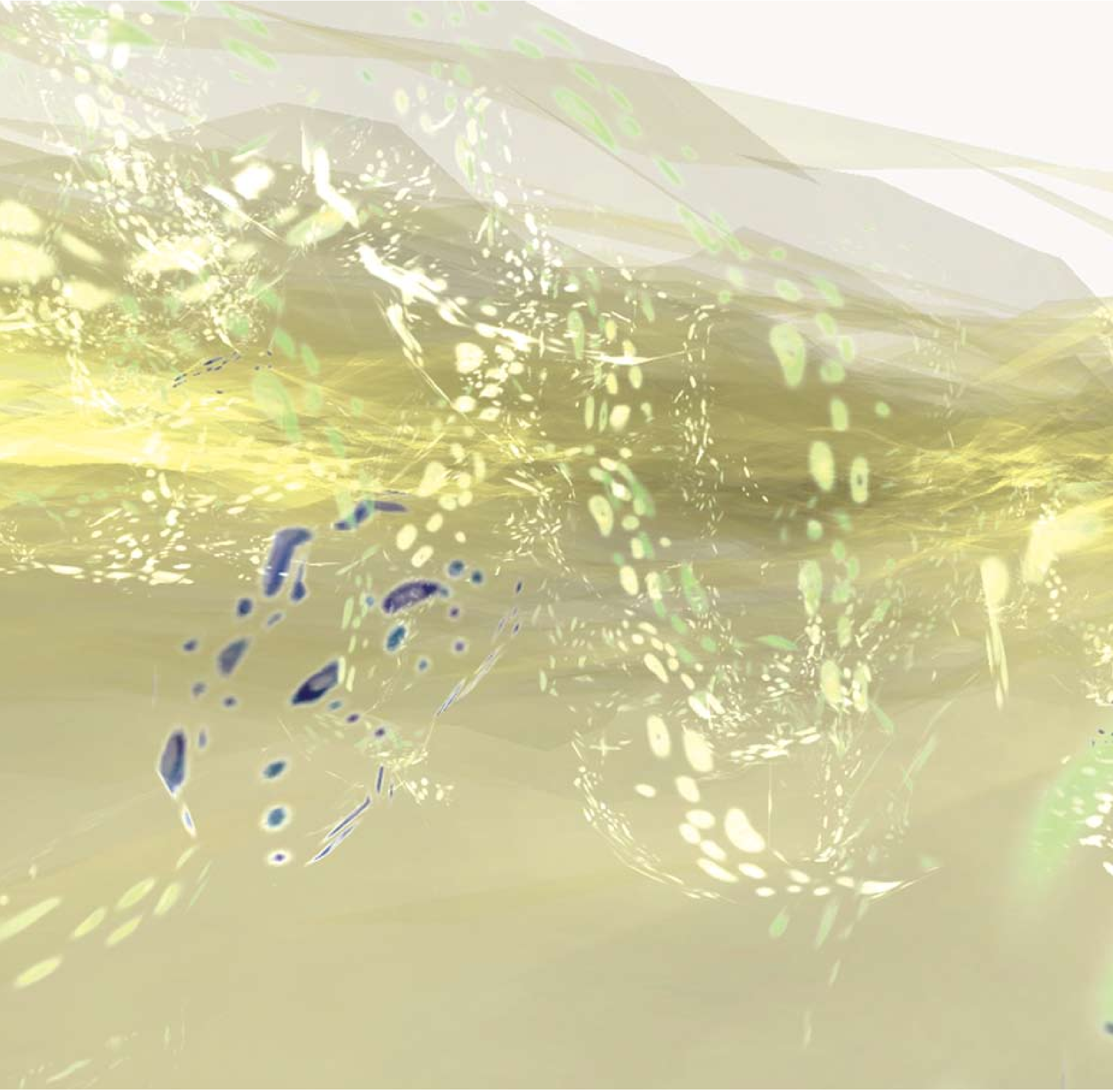
Nano_essence is an interactive audio-visual installation where the viewer interfaces with the visual and sonic presentation through his or her own breath. In the context of the project breath has a strong conceptual and metaphorical link to a Biblical inception of life. The project attempts to maintain a high quality of authentic data to engage the viewer in a sensorial qualitative experience of quantitative data.

The *Nano_essence* project research is based on data gathered as part of a residency at SymbioticA, Centre of Excellence in Biological Arts, University of Western Australia and the Nanochemistry Research Institute, (NRI) Curtin University of Technology.

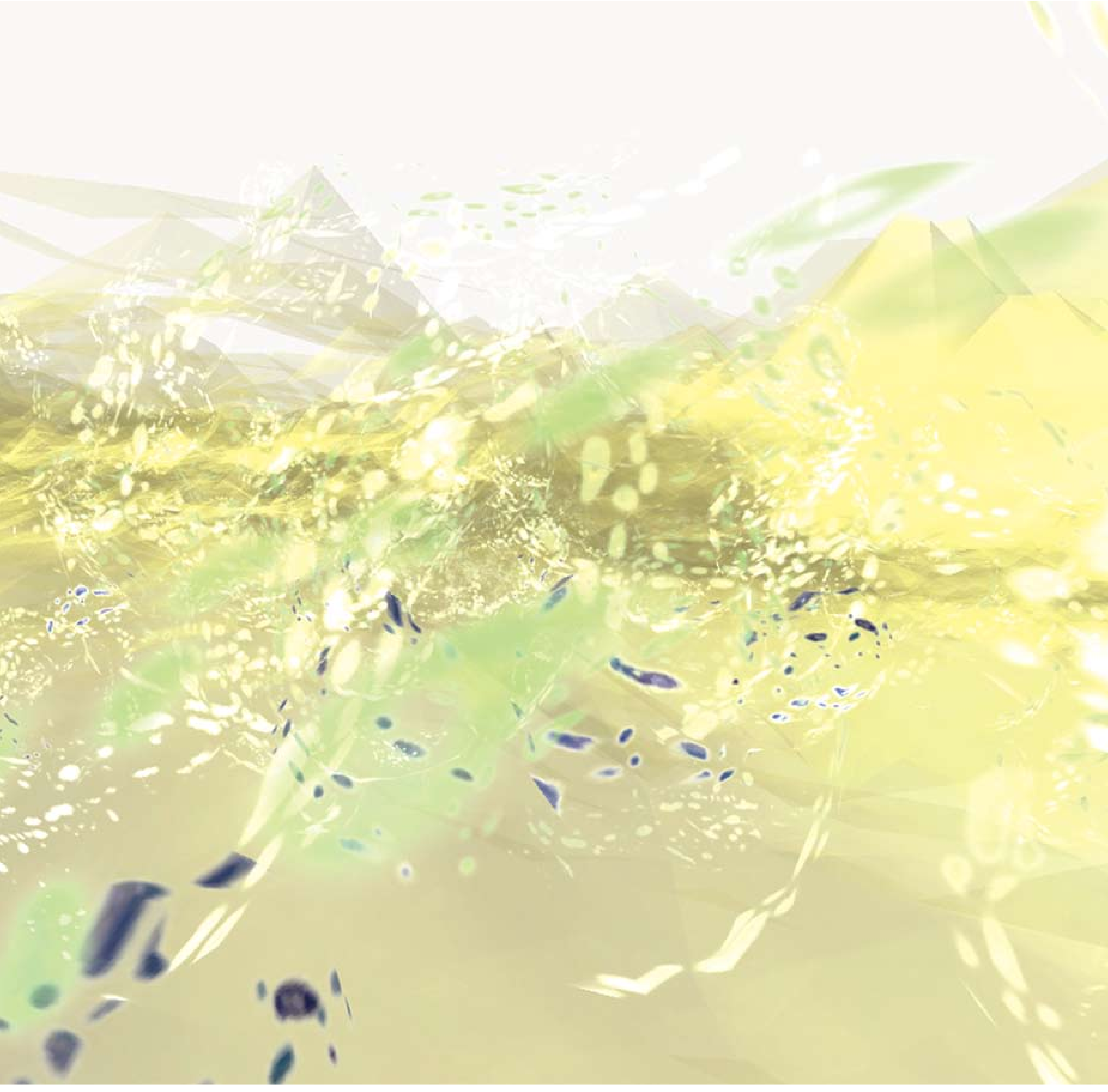
Paul Thomas and Kevin Raxworthy, ***Nano_essence: breath interface***, 2009, digital image, image courtesy of the Artists



Paul Thomas and Kevin Raxworthy, ***Nano_essence 1***, 2009, screen capture, image courtesy of the Artists



Paul Thomas and Kevin Raxworthy, ***Nano_essence 2***, 2009, screen capture 2009, image courtesy of the Artists



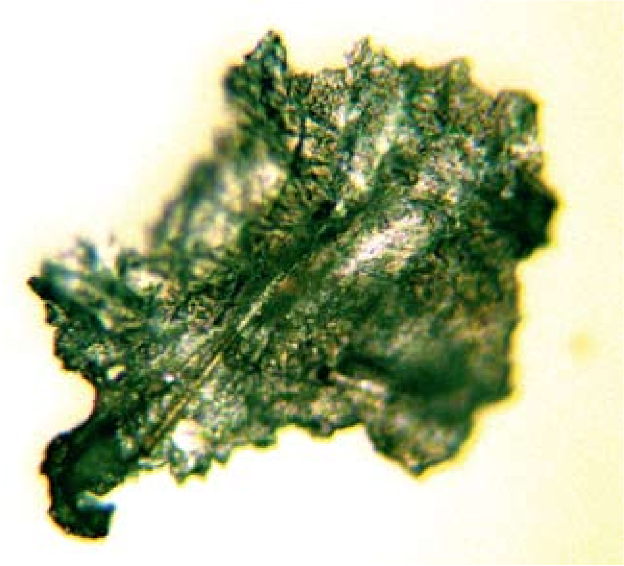
A Mote it is... 2009 **Mike Phillips**

"A mote it is to trouble the mind's eye".[1]

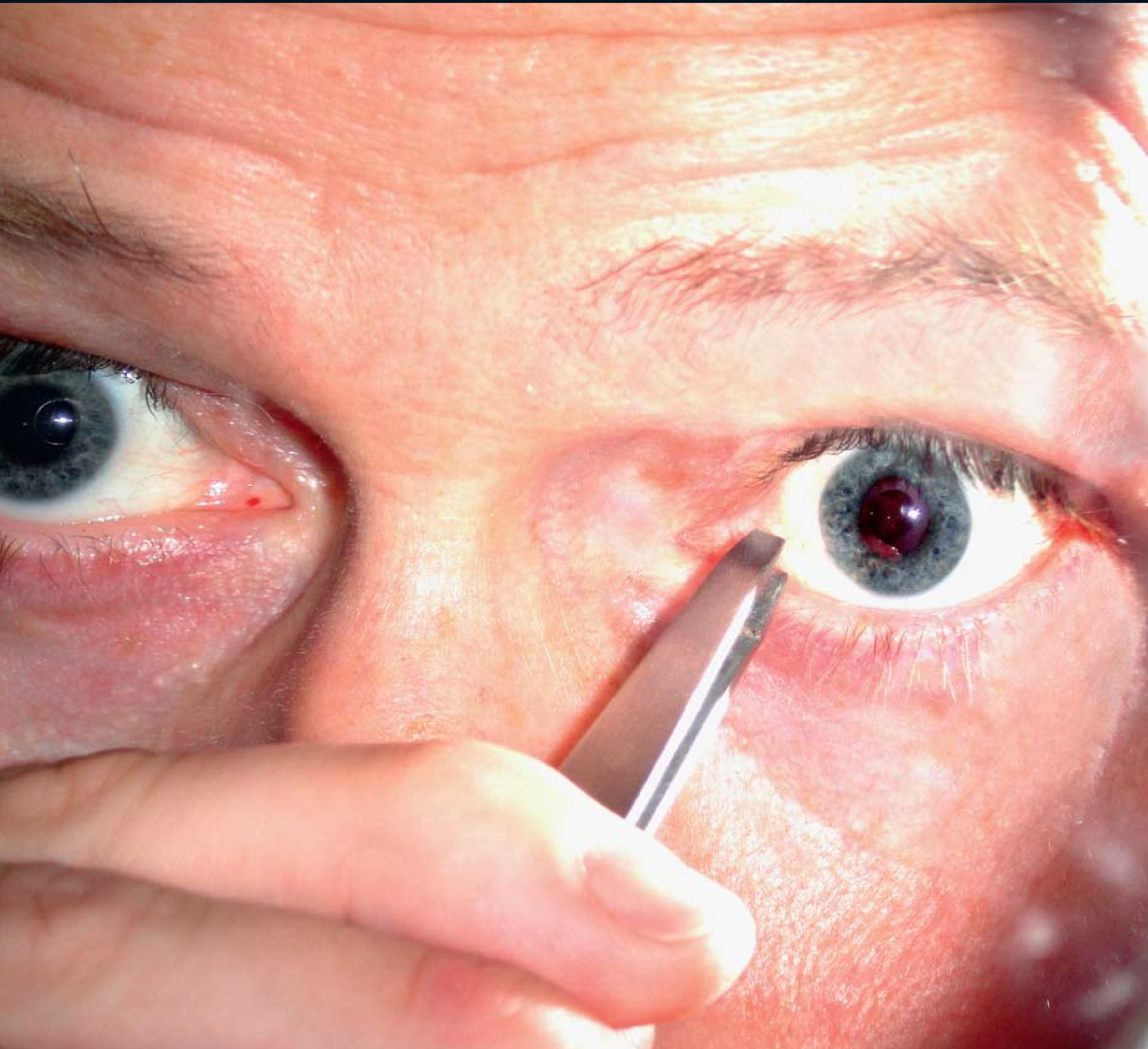
Words spoken by Horartio to describe the ghost of Hamlet's father. In this Shakespearian play the ghost is seen but not believed and one is left to wonder if it is just the seeing of it that makes it real – its existence totally dependent on the desire of the viewer to see it. The 'mote' or speck of dust in the eye of the mind of the beholder both creates the illusion and convinces us that what we see is real. Something just out of the corner of our minds eye, those little flecks magnified by our desire to see more clearly. Yet the harder we look the more blurred our vision becomes.

A 'mote' is both a noun and a verb. Middle English with Indo-European roots, its early Christian origins and Masonic overtones describe the smallest thing possible and empower it with the ability to conjure something into being (*so mote it be...*). This dual state of becoming and being (even if infinitesimally tiny) render it a powerful talisman in the context of nanotechnology.

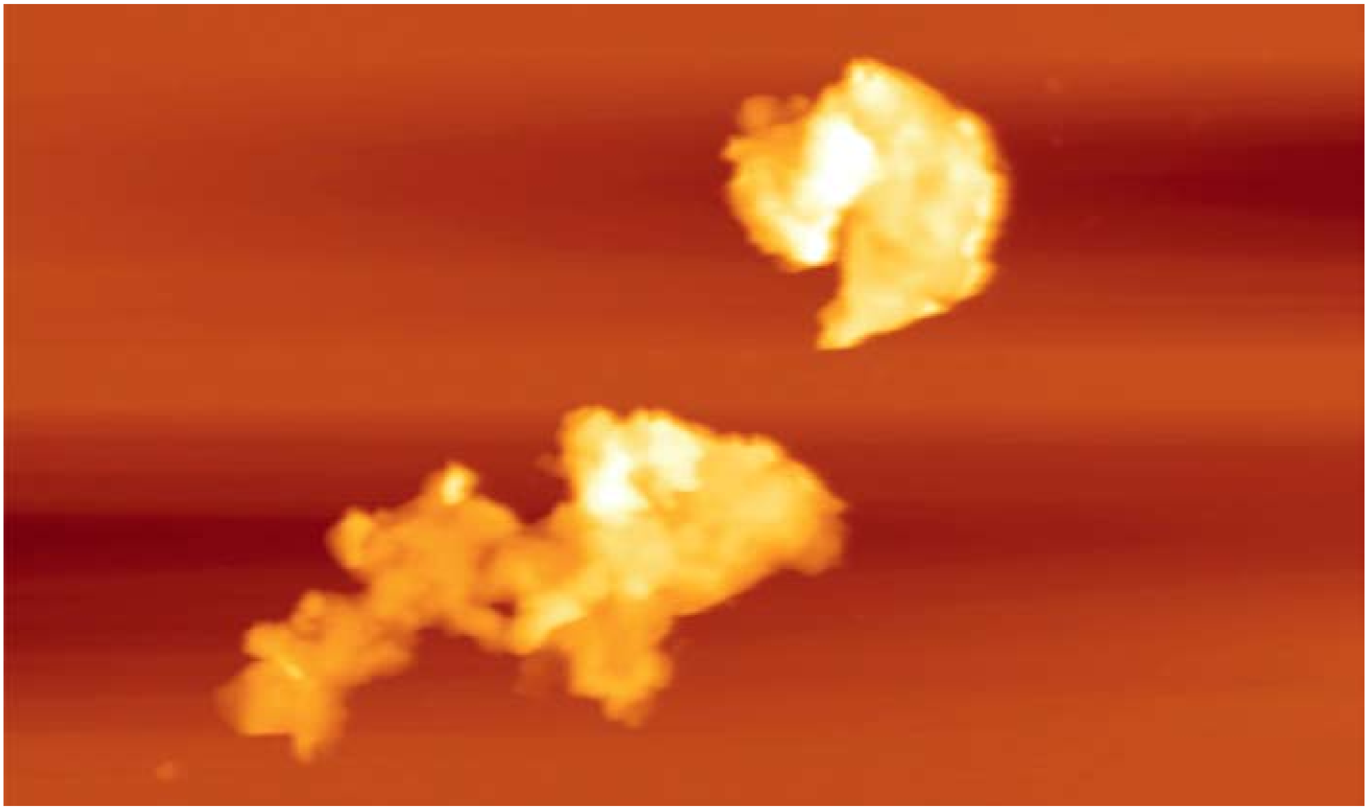
Throughout the last Century we were reintroduced to the idea of an invisible world. The development of sensing technologies allowed us to sense things in the world that we were unaware of (or maybe things we had just forgotten about?). The invisible 'Hertzian' landscape was made accessible through instruments that could measure, record and broadcast our fears and desires. Our radios, televisions



Mike Phillips, ***A Mote***, 2009, microscope digital image, image courtesy of the Artist



Mike Phillips, ***Extracting a Mote***, 2009, digital image, image courtesy of the Artist



Mike Phillips, ***AFM Mote***, 2009, AFM digital image, image courtesy of the Artist

and mobile phones revealed a parallel world that surrounds us. These instruments endow us with powers that in previous centuries would have been deemed occult or magic.

Our Twenty First Century magic instruments mark a dramatic shift from the hegemony of the eye to a reliance on technologies that do our seeing for us – things so big, small or invisible that it takes a leap of faith to believe they are really there. Our view of the 'real world' is increasingly understood through images made of data, things that are measured and felt rather than seen. What we know and what we see is not the same thing – if you see what I mean? The worrying thing is that for a long time we thought the invisible world was made of layers of transparent electromagnetic fields, now through technologies such as the Atomic Force Microscope (AFM) we are faced with the reality that the 'invisible' is actually what constitutes our material world, we can reach out and touch it!

It is our relationship with these technologies that troubles the mind's eye. Our ability to shift scales, from the smallest thing to the largest thing has been described as the 'transcalar imaginary'.[2] In this context astronomer Carl Sagan described the Earth as a "mote of dust, suspended in a sunbeam".[3] The famous image taken from Voyager 1 in 1990 shows the planet suspended in an infinite Universe. A mote that seems so large to us, but which is in fact so cosmologically small, disturbs our sensibilities and desire for order in our world.

About *A Mote it is...*:

A Mote it is... is constructed from data captured by an AFM from a 'mote' or piece of dust extracted from the artist's eye. The whirlwind of data projected within the gallery is rendered invisible by the gaze of the viewer. The more we look the more invisible it becomes - look away and it re-emerges from the maelstrom of data. A ghost of the mote can be seen in viewers peripheral vision but never head on – if you see what I mean?

NOTES:

1. Shakespeare, W. Hamlet. Act 1, Scene 1, Line 129.
2. http://www.twine.com/twine/12vx9k6qs-2zp/transcalar-imaginary
3. *Sagan, C. 1994,Pale Blue Dot*, Random House. p6

Many thanks to:

Lee Nutbean at i-DAT.

Professor Genhua Pan and Yuqing Du at the Wolfson Nanotechnology Laboratory at University of Plymouth.

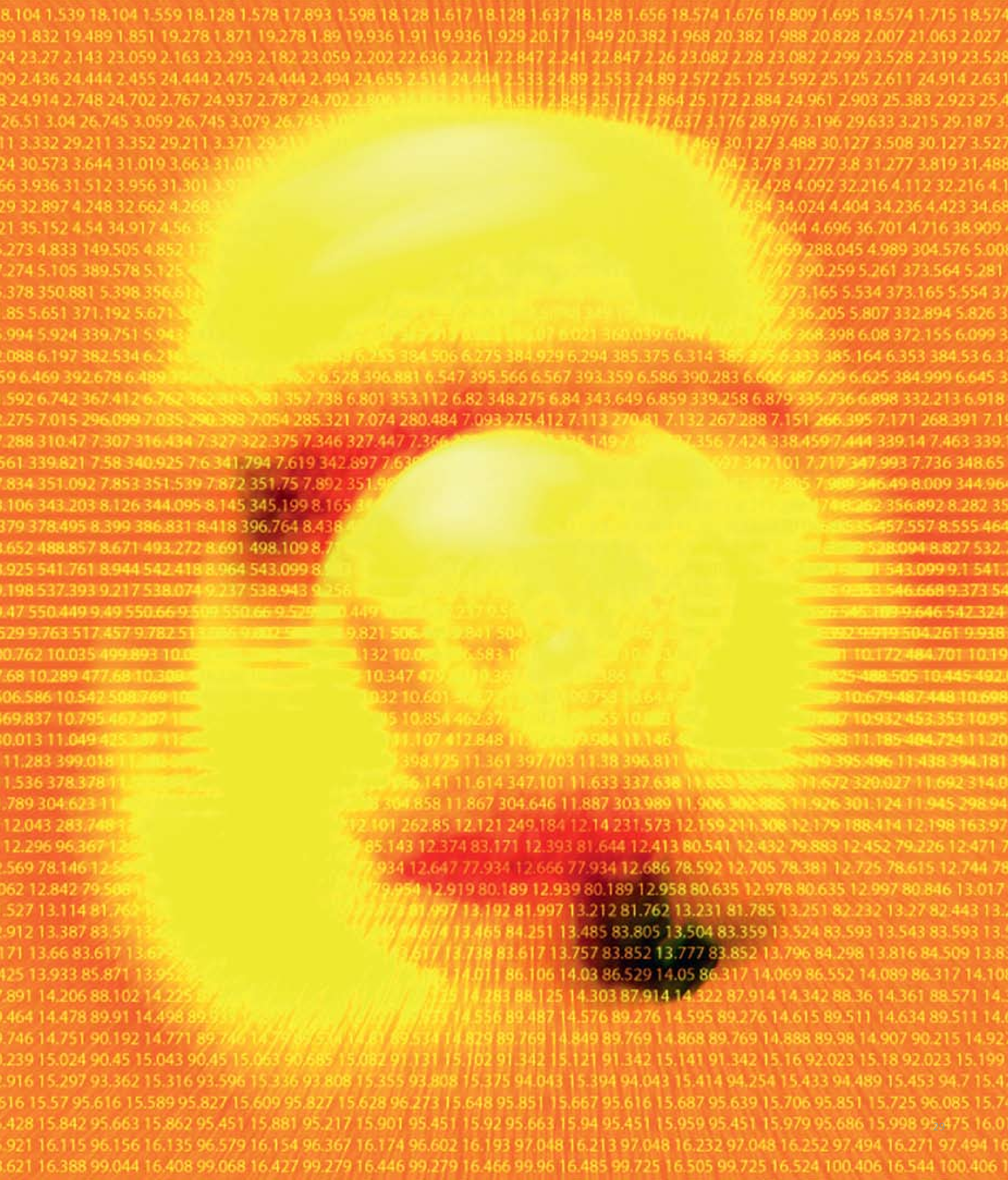
www.nascent-research.net

http://www.i-dat.org

www.arch-os.com

www.liquidpress.net

(opposite) Mike Phillips, ***Data Mote*** (work in progress), 2009, screen capture, image courtesy of the Artist



NANOMANDALA © 2003 **Victoria Vesna and James Gimzewski**

The ***Nanomandala*** is an installation by media artist Victoria Vesna, in collaboration with nanoscience pioneer James Gimzewski. The installation consists of a video projected onto a disk of sand, 8 feet in diameter. Visitors can touch the sand as images are projected in evolving scale from the molecular structure of a single grain of sand to the recognizable image of the complete mandala, and then back again.

This coming together of art, science and technology is a modern interpretation of an ancient tradition that consecrates the planet and its inhabitants to bring about purification and healing. The sand mandala of *Chakrasamvara* seen in this installation was created by Tibetan Buddhist monks from the Gaden Lhopa Khangtsen Monastery in India, in conjunction with the *Circle of Bliss* exhibition on Nepalese and Tibetan Buddhist Art at the Los Angeles County Museum of Art in 2002. This particular sand mandala had never before been made in the United States. To complement the video, sound artist Anne Niemetz has developed a meditative soundscape derived from sounds recorded during the creative process of making the sand mandala.

Of the installation Vesna says: "Inspired by watching the nanoscientist at work, purposefully arranging atoms just as the monk laboriously creates sand images grain by grain, this work brings together the Eastern and Western minds through their shared process centered on patience. Both cultures use these bottom-up building practices to create a complex picture of the world from extremely different perspectives".

The artist / scientist collaborators continue to pursue the philosophical connection of Buddhism to nanoscience and ideas of 'empty space'. In 2006, they organized, *Thinking Atoms*, a panel that brought into the dialogue a Tibetan lama, neuroscientist, philosopher and community organizer.

About Chakrasamvara

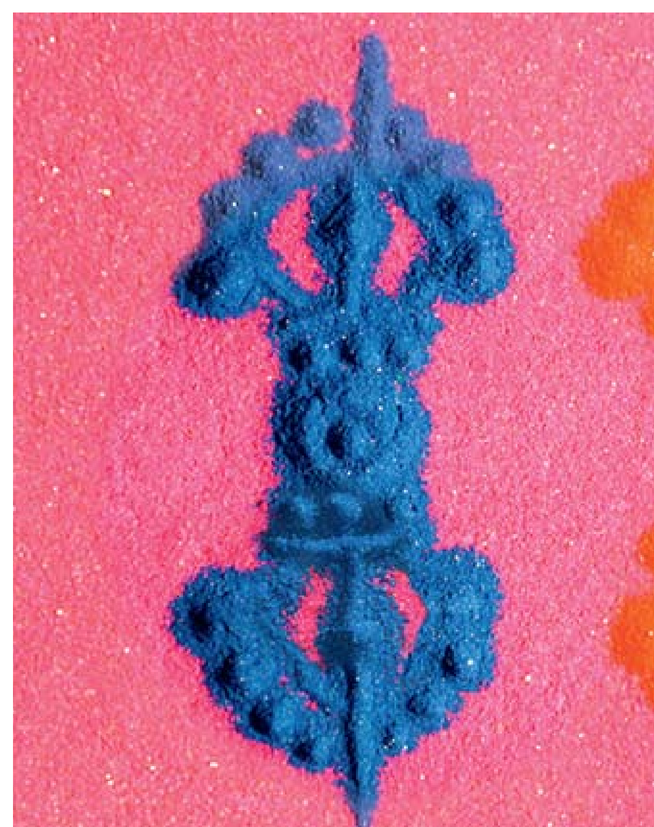
Chakrasamvara and *Vajravarahi* embody the enlightened Buddhas of the Highest Yoga Tantras, whose symbolism and meditation are intended to lead the Tantric practitioner directly to enlightenment within this lifetime. To realize the state of enlightenment, the Chakrasamvara practice places special emphasis on the attainment of the radiant light of bliss (prabhasvara) that is generated through the union of Chakrasamvara and Vajravarahi. This process is called devayoga, literally meaning 'uniting with the gods', in which the yogin acquires the qualities of the visualized beings and therefore understands his or her identity with the fully realized Buddhas.

The meditation begins by visualizing the glorious body of Chakrasmavara, and completes with the visualizations of Vajravarahi, as the inner purifying fire. This state of absolute nonduality-the cessation of all desire and quiescence of all egoistic constructs-is nowhere more powerfully symbolized than by the union of Chakrasamvara and Vajravarahi. Their eternal and indivisible union forcefully unites wisdom and compassion into a completely realized state of nonduality.

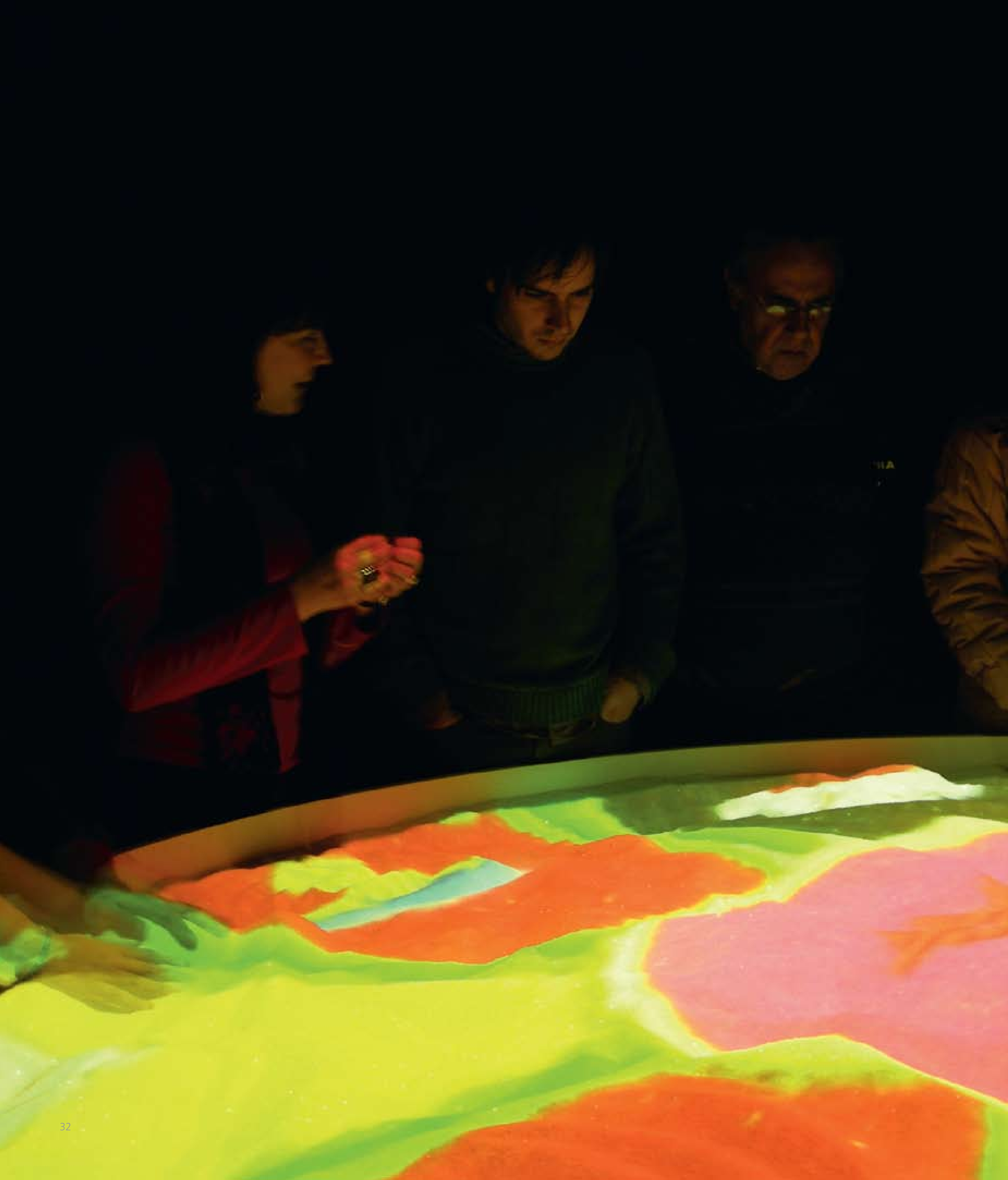
LINKS:

Nanomandala: http://nano.arts.ucla.edu/mandala
Thinking atoms polylogue: http://artsci.ucla.edu/artsci/events/thinkingatoms.html

The method is to imagine a sequence of stages and transformations and to practice them repeatedly until they are completely internalized. At each stage, the works of art aid the practitioner to understand the iconography and interpretive symbolism of Chakrasamvara/Vajravarahi as well as the sixty-two deities of the Chakrasamvara mandala.



(images pages 31 – 33) Victoria Vesna, James Gimzewski and Tibetan Buddhist monks from the Gaden Lhopa Khangsten monastery, ***Nanomandala***, 2003, installation details, images courtesy of the Artist



Nano-Scape © 2002 **Christa Sommerer & Laurent Mignonneau**

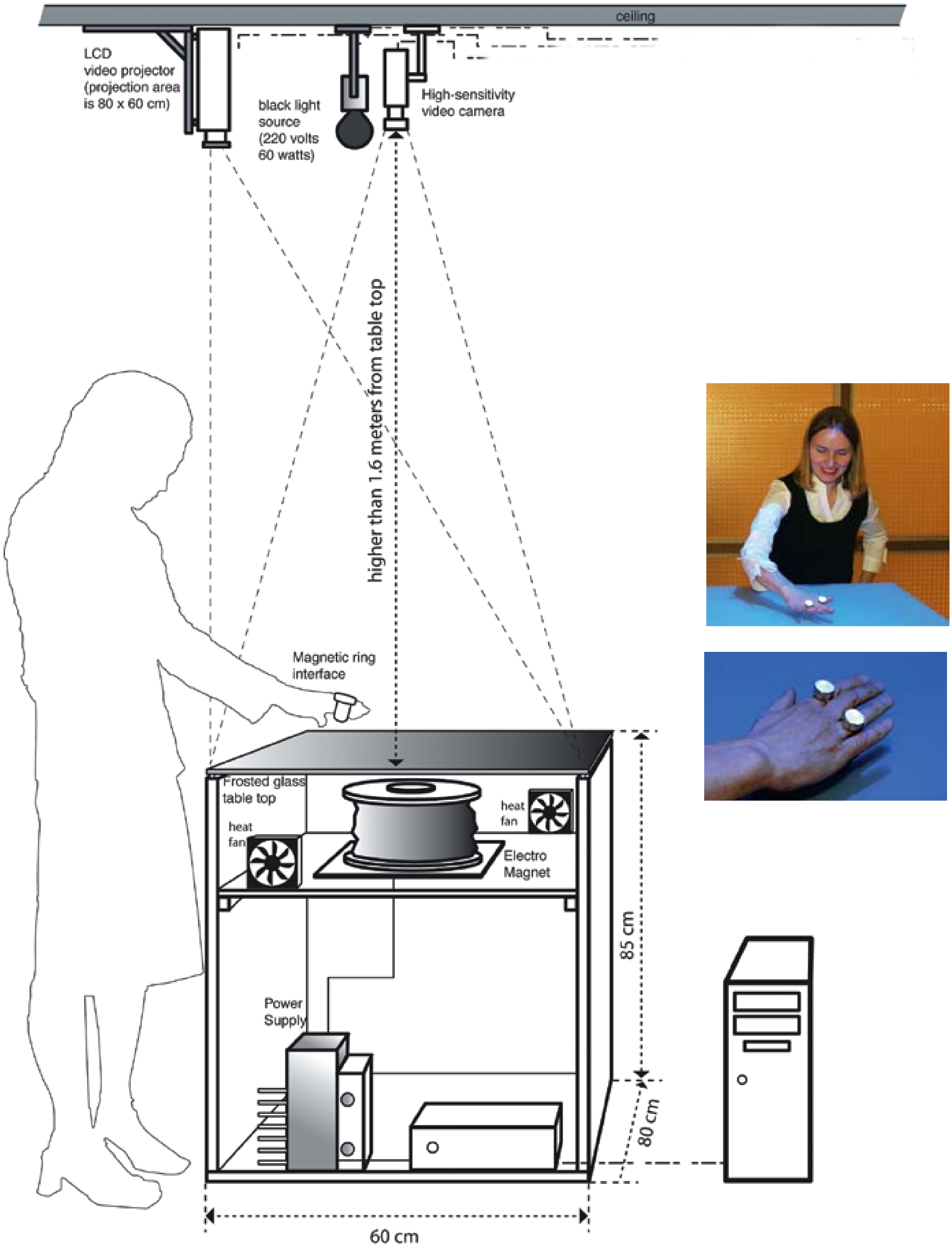
For our ***Nano-Scape*** system we combined the research areas: nanotechnologies, haptic user interaction and self-organising systems. Our goal was not so much to show pure data or facts but to let users intuitively experience aspects of nanotechnology through a haptic user interface and to show how intricate and complex interactions on a nano-scale level can be.

Nano-Scape combines an electromagnetic force-feedback interface with a camera-based hand tracking system and an atomic force simulation. Users of this system can interactively feel invisible magnetic forces of simulated atoms that seem to 'float' above the surface of a large glass table. Users who wear special magnetic ring interfaces can feel the atoms' interaction forces as they move their hands above the glass table's surface. When the hand is moved above the table's surface, the camera tracks the exact position of the magnetic ring and sends this information to an atomic-force simulation. This simulation calculates the attraction and repulsion forces between simulated atoms.

Our atomic force simulation is based on a group of approximately 120 simulated atoms that constantly react to each other depending on the forces that reign between them. We loosely modeled the system on atoms with no valence electrons, based on Kaxira's description. He describes:

> "atoms with all their electronic shells completely filled, which in gaseous form are very inert chemically, i.e. the noble elements Ha, Ne, Ar, Kr and Xe. When these atoms are brought together to form solids they interact very weakly. Their outer electrons are not disturbed much since they are essentially core electrons, and the weak interaction is the result of slight polarisation of the electronic wave function in one atom due to the presence of other atoms around it. Fortunately, the interaction is attractive. This interaction is referred to as 'fluctuating dipole' or van der Waals interaction. Since the interaction is weak, the solids are not very stable, and they have very low melting temperatures, well below room temperature. The main concern of the atoms in forming such solids is to have as many neighbors as possible, in order to maximise the cohesion since all interactions are attractive. The crystal structure that corresponds to this atomic arrangement is one of the close-packing geometries, that is, arrangements which allow the closest packing of hard spheres. The particular crystal structure that noble-element atoms assume in solid-state form is called face-centered cubic (FCC). Each atom has 12 equidistant nearest neighbors in this structure".[1]

Since our system needed to be interactive, and calculating forces of 12 neighbors for each atom would have been too computationally intensive, we decided to create a simplified 2D simulation of these van der Waals forces. We modeled a set of 100 atoms, where the forces between them are based on the criteria to "have as many neighbors as possible, in order to maximize the cohesion since all interactions are



Christa Sommerer and Laurent Mignonneau, 2002, ***Nano-Scape: setup drawing***. Supported by Volkswagenstiftung, Hannover. Image courtesy of the Artists

attractive" as described by author, Efthimios Kaxiras. The resulting image of this simulation is one where all atoms are at a state of equilibrium in terms of attractive and repulsive forces towards their neighbors.

Once movement disturbs the system, it will take into account the actual position of the user's magnetic ring and recalculate the forces between the neighboring atoms. Since all 120 atoms are linked to each other, each smallest disturbance will lead to a re-arranging of forces between all the atoms while they try to go back into the equilibrium state. A user can feel the effect of their interaction with these simulated atoms through the magnetic force feedback interface. This feedback is achieved by connecting the actual forces received by the red atom from its neighboring atoms to the strength of the electromagnetic field produced between the electromagnet and the permanent magnetic ring interface. In other words, our simulation calculates the given strength of the forces that occur upon the red atom and sends this data back to the electromagnet, which produces a corresponding electromagnetic field that can be picked up and felt by the user through his magnetic ring interface. For example, when the user moves their hand very strongly over the table's surface and thus strongly disturbing the invisible atoms, the electromagnetic feedback forces upon the user's ring will also become very strong. At times to the point where the magnetic ring will start to vibrate. On the other hand, when the system is almost at equilibrium, the forces felt by the user are smaller as well. However each interaction disturbs the system, so the user will never be able to experience the system in full equilibrium.

The users of the system do not see the atomic force simulation as it is displayed on a monitor outside of the installation space. This was a conscious decision, firstly because the nano-world is usually not visible, and secondly because the display of visual information would have distracted the users from feeling the atomic forces. Gault describes touch as a very strong "break-in" sense: coetaneous sensations, especially if aroused in unusual patterns.[2] In one of our previous haptic interfaces we also found that visual or auditory information could impair the haptic experience.[3]

We have developed an intuitive interactive installation that was able to raise public awareness of nanotechnologies by showing how complex and intricate interactions of atoms are on a nano-scale level. We combined several areas of research including nanotechnologies, haptic user interaction and self-organising systems. In the future we aim to further explore how the nanosciences in general can inspire new forms of artistic expression by designing the "strange futures, holding worlds beyond our imagining," that Drexler describes.[4]

Nano-Scape was developed for the exhibition *'Science+ Fiction'*[5] at the Sprengelmuseum, Hannover and was supported by the Volkswagenstiftung, Hannover It was shown at the ZKM, Karlsruhe and supported by IAMAS Institute of Advanced Media Art and Sciences in Gifu, Japan. A full version of this article was first published in 2005.[6]

NOTES:

1. E. Kaxiras, *Atomic and Electronic Structure of Solids* (Cambridge: Cambridge University Press, 2003), 7–10.
2. R. Gault, "Progress in experiments on tactual interpretation of oral speech," *Journal of Abnormal and Social Psychology* 14 (1925): 155–159.
3. C. Sommerer and L. Mignonneau, "Mobile Feelings – wireless communication of heartbeat and breath for mobile art," in *14th International Conference on Artificial Reality and Telexistance (ICAT2004) Conference Proceedings, Seoul, South Korea* (2004), 346–349.
4. K. E. Drexler, *Engines of Creation: The Coming Era of Nanotechnology* (New York: Anchor Press, 1986; reprint, New York: Anchor Press, 1987).
5. Volkswagenstiftung, "Science+Fiction," http://www.scienceandfiction.de/
6. C. Sommerer and L. Mignonneau, "Nano-Scape: experiencing aspects of nanotechnology through a magnetic force-feedback interface," in *Proceedings of ACM SIGCHI International Conference on Advances in Computer Entertainment Technology, ACE 2005, June 15–17, 2005, Valencia, Spain,* ed. Newton Lee (New York: ACM, 2005), 200–203.


Christa Sommerer and Laurent Mignonneau, 2002, ***Nano-Scape: user 06***. Supported by Volkswagenstiftung, Hannover. Image courtesy of the Artists

Transjuicer 2010 **Boo Chapple**

Transjuicer represents the culmination of several years of work on the project to make audio speakers out of bone. Practically, this has involved working with the piezoelectric nature of the bone matrix in order to cause the bone to vibrate in such a way as to generate sound.

Piezoelectricity is a characteristic of certain types of crystals and polymers, such that when they are subjected to a mechanical pressure or stress they develop a charge separation, or voltage, across two opposing faces. Conversely, when a voltage is applied to the same material it will, depending on the polarity of the voltage, physically expand or contract at the nanometre scale. It follows that when an oscillating AC voltage is applied to a piezoelectric material it will expand and contract at the same frequency as the AC signal. This principle is used to make piezoelectric buzzers and audio speakers out of industrially manufactured piezo ceramics. The piezoelectric nature of the bone matrix itself has been documented by a number of different scientists in publications that date back to initial research into the phenomenon by the Japanese physicists Fukada and Yasuda in 1957.

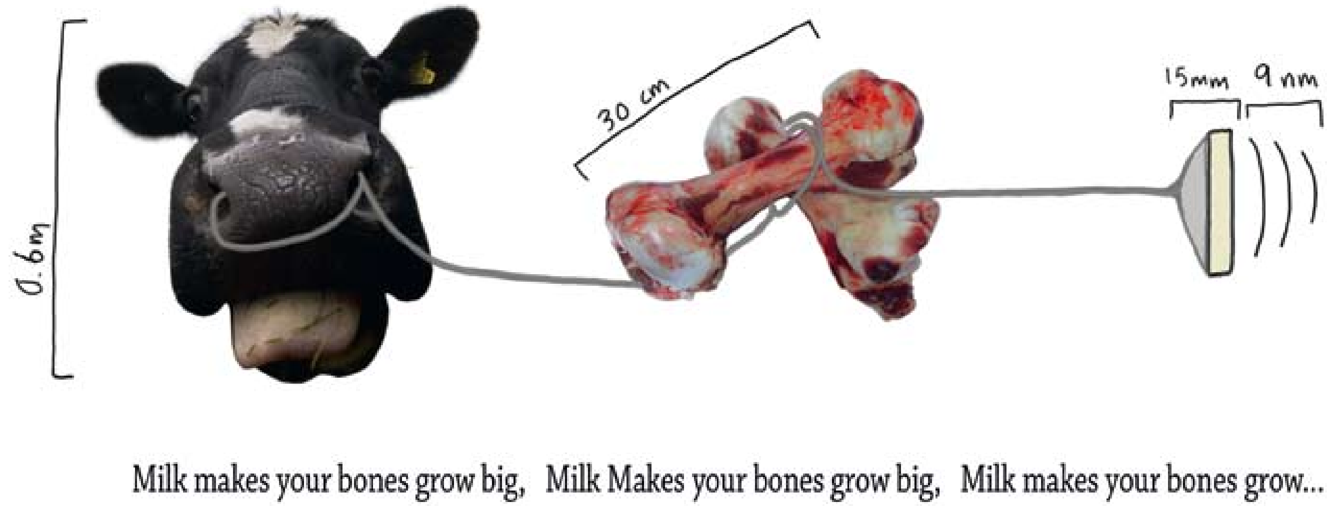
What initially interested me about this particular property of bone, was the way in which it speaks to the complex and dynamic entanglements that exist between life and world; to the incredibly fine resolution at which bodies are continually in communication with their physical environment. Paradoxically, in order to utilise the dynamic qualities of bone to make an audio speaker it was necessary to remove the bone from its living context and so a work that began as an investigation of living dynamism became a process of material transformation that proceeded from butcher to technological artefact. With each discrete stage in the process, we achieved a greater degree of refinement. The material under consideration became smaller and smaller. From the rotting tank where we cleaned the bone, to the square cut sections, to the routing of the laser signal of the vibration detection system through photodetector, amplifier and oscilloscope, until we captured a response. Yes, the bone responds, it vibrates at the nanoscale, generating sound softer than we can hear, performing the complex of technical, material, socio-cultural and economic contexts through which it came into being.

While all technologies operate in this manner – actively performing their process of coming into being in the world – experimental technologies tend to be less polished, and hence, more overt in the relationships that they manifest. I am reminded of Alexander Graham Bell's ear phonautograph, in which he used the tympanic membrane from the ear of a human cadaver to trace sound waves on a sheet of glass; a grisly invention that combines a dubious appropriation of human remains with one of the first ever audio recordings.

Death and progress have been long time bedfellows in the history of human techno-economic ascendency. So what about the cow? What is activated by the use of cow bone

(opposite) Boo Chapple, ***Transjuicer 1***, 2010, digital image, image courtesy of the Artist

Transjuicer: Rack Mount Totem One



in this work? In fact, the trajectory of instrumentalisation represented in the bone audio speaker does not begin at the butcher – it begins way back with the domestication of the cow itself. In order to delve further into this history, I went on a research expedition to a local dairy farm, where I was able to experience – in the form of the milking machine – the intimate interface between cow and machine already existing at the heart of our everyday consumption practices. The bones now on display with the speakers were dug up from the dairy 'graveyard' and footage of the milking machine is central to the video component of the work.

So what does the cow bone audio speaker, the piezoelectric transducer, actually transduce? At the purely material level it transduces electromagnetic waveforms – in this case of dairy sounds, bone songs, cow songs, milk songs – into nano-sonic vibrations. These vibrations have been recorded using a laser interferometer and can be listened to on headphones. At another level again, the speaker transduces between macro social context and micro technical interventions, between the cow and the gallery, between the dead and the living, between science and representation. The recordings themselves are indistinct and full of static, part artefact of a piece of bone moving and part noise from the process of attempting to record something so small. They are like the far away voices of ghosts that inventors such as Bell once thought were communicated via the 'occult force' of electricity and in this respect, the speakers capture something of the mysticism that often surrounds representations of the 'nano-world' in contemporary culture. They sit like antennas atop a totem of transformation – part science, part belief, part cow, part device, part art, and part life.

Research conducted in collaboration with William Wong, final year student, Engineering/Science, OBEL, University of Western Australia.

This project was facilitated by SymbioticA, OBEL and Professor David Sampson and assited by the Australian Government through the Australia Council for the Arts, its arts and advisory body.

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Fukada, E. & Yasuda, I., 'Piezoelectric Effects in Collagen', *Japanese Journal of Applied Physics*, Vol. 3, No. 2, 117-121 (1964).

(above) Boo Chapple, ***Transjuicer 2***, 2010, digital image, image courtesy of the Artist

Nano offers the means of reality checking and reality building, a superimposition that finds its continuum in the field of consciousness.

Roy Ascott, Professor of Technoetic Arts, School of Computing, Communications and Electronics, University of Plymouth, UK (*Info-Light: Art, Technoetics and the Biophotonic Network*. Ciberart: Challenges for a Ubiquitous Identity, Bilbao; 2004)

Artists' Biographies

Dr Paul Thomas is Associate Professor and Director of the Centre or Research in Art, Science and Humanity at Curtin University of Technology. Thomas has been working in the area of electronic arts since 1981 when he co-founded the group *Media-Space*, which was part of the first global link up with artists connected to ARTEX. From 1981-1986 the group was involved in a number of collaborative exhibitions and was instrumental in the establishment of a substantial body of research.

In 2000, he founded the Biennale of Electronic Arts Perth. Thomas's current research project *Nano_essence* explores the space between life and death at a nano level. The project is part of an ongoing collaboration with the Nano Research Institute, Curtin University of Technology and SymbioticA at the University of Western Australia.

Thomas is also currently working on an intelligent architecture project for the Curtin Mineral and Chemistry Research Precinct Public art project. The art project is integrated into the two new buildings that will form the Resource and Chemistry Precinct.

He is the co-chair of the *Re:live media art history* conference 2009. Thomas is a practicing electronic artist whose work has exhibited internationally and can be seen on his website www.visiblespace.com.

Kevin Raxworthy is Senior Technician in the Studio of Electronic Arts (SEA) at Curtin University of Technology. Raxworthy has been working in the area of media art since 1983. He was the technical support officer for the Biennale of Electronic Art Perth 2002 and 2004. Raxworthy has been working in collaboration with Paul Thomas on the *Midas Project* that was exhibited at Enter 3 Prague in 2007. In their current project *Nano_essence* he is writing an algorithm based on cellular automaton. The algorithm is affected and stimulated by using the different information gained from sensors that read the user's breath. Raxworthy's work looks at the nexus between artificial life, code space and art. He is currently completing his masters in electronic art.

Mike Phillips is Reader in Digital Art & Technology, University of Plymouth, School of Computing, Communications & Electronics, Faculty of Technology. Phillips is Director of i-DAT and heads the Nascent Art & Technology Research Group. His transdisciplinary R&D orbits digital architectures and transmedia publishing, and is manifest in two key research projects: Arch-OS, an 'Operating System' for contemporary architecture ('software for buildings') and the Liquid Press which explores the evolution and mutation of publishing and broadcasting technologies.

Victoria Vesna is a Media Artist and Professor at the Department Of Design | Media Arts at the Universirty of California, Los Angeles (UCLA) School of the Arts. She is also director of the recently established UCLA Art|Sci center and the UC Digital Arts Research Network.

Vesna's work can be defined as experimental creative research that resides between disciplines and technologies. She explores how communication technologies affect collective behavior and how perceptions of identity shift in relation to scientific innovation. Her most recent installations – *Blue Morph*, *Mood Swings* and *Water Bowls*, all aim to raise consciousness around the issues of our relationship to natural systems. Other notable works are *Bodies INCorporated*, *Datamining Bodies*, *n0time* and *Cellular Trans_Actions*.

Vesna has exhibited her work in 18 solo exhibitions, over 70 group shows, published more than 20 papers and has given over 100 invited talks in the last decade. She is the recipient of many grants, commissions and awards, including the Oscar Signorini award for best net artwork in 1998 and the Cine Golden Eagle for best scientific documentary in 1986. Vesna's work has received notice in numerous publications such as *Art in America*, *National Geographic*, the *Los Angeles Times*, *Spiegel* (Germany), *The Irish Times* (Ireland), *Tema Celeste* (Italy), and *Veredas* (Brazil) and appears in a number of book chapters on media arts. She holds a PhD from the University of Wales and is the North American editor of *AI & Society* and author of *Database Aesthetics*.

James Gimzewski is a Distinguished Professor of Chemistry at the University of California, Los Angeles (UCLA); Director of the Nano & Pico Characterization Core Facility of the California NanoSystems Institute; Scientific Director of the Art|Sci Center and Principal Investigator and Satellites Co-Director of the WPI Center for Materials NanoArchitectonics (MANA) in Japan.

Prior to joining the UCLA faculty, he was a group leader at IBM Zurich Research Laboratory, where he researched in nanoscale science and technology for more than 18 years. Dr Gimzewski pioneered research on mechanical and electrical contacts with single atoms and molecules using scanning tunneling microscopy (STM) and was one of the first persons to image molecules with STM. His accomplishments include the first STM-based fabrication of molecular suprastructures at room temperature using mechanical forces to push molecules across surfaces, the discovery of single molecule rotors and the development of new micromechanical sensors based on nanotechnology, which explore ultimate limits of sensitivity and measurement. This approach was recently used to convert biochemical recognition into Nanomechanics.

His current interests are in the nanomechanics of cells and bacteria where he collaborates with the UCLA Medical and Dental Schools. He is involved in projects that range from the operation of X-rays, ions and nuclear fusion using pyroelectric crystals, direct deposition of carbonn nanotubes and single molecule DNA profiling. Dr. Gimzewski is also involved in numerous art-science collaborative projects that have been exhibited in museums throughout the world.

Christa Sommerer and Laurent Mignonneau are internationally renowned media artists and researchers, they have jointly created around 20 interactive artworks, which can be found at http://www.interface.ufg.ac.at/christa-laurent.

These artworks have been shown in around 200 exhibitions world-wide and are installed in media museums and media collections around the world, including the Van Gogh Museum in Amsterdam, the Museum of Science and Industries in Tokyo, the Media Museum of the ZKM in Karlsruhe, the Cartier Foundation in Paris, the Ars Electronica Center in Linz, the NTT-ICC Museum in Tokyo, the NTT Plan-Net in Nagoya, Japan, the Shiroishi Multimedia Art Center in Shiroishi, Japan, the HOUSE-OF-SHISEIDO in Tokyo and the ITAU CULTURAL Foundation in Sao Paulo.

Mignonneau and Sommerer's interactive artworks have been called "epoch making" (Toshiharu Itoh, NTT-ICC museum Tokyo) for developing natural and intuitive interfaces and for often applying scientific principles such as artificial life, complexity and generative systems to their innovative interface designs. They have won major international media awards, among others the "Golden Nica" Prix Ars Electronica Award for Interactive Art 1994 (Linz, Austria).

Mignonneau and Sommerer have published on Artificial Life, Complexity, interactivity and interface design and have lectured extensively at universities, international conferences, and symposia. They have worked as researchers and professors at ATR Research Labs in Kyoto Japan and at IAMAS in Ogaki Japan for 10 years and are currently heading the department for Interface Cultures at the University of Art and Design in Linz, Austria which specialises on interactive art, interactive media and interface design.

Boo Chapple is an Australian artist whose conceptually driven practice has been enacted across a diverse range of media including sound, performance, installation, video, and art/science projects. In the past she worked as a sound artist, technician and tour manager on a number of theatre based performance projects and since 2004 she has maintained an interdisciplinary teaching practice (Media, Industrial Design, Art/Science).

In 2006 she completed a year-long residency at SymbioticA, University of Western Australia, funded by the New Media Board of the Australia Council and in 2007–08 she undertook a twelve-month residency at the Design Research Institute, RMIT, funded by an Arts Innovation grant from Arts Victoria. In 2009, Chapple taught the annual Vivo Arts Course at the Art and Genomics Centre, Leiden, The Netherlands.

Chapple has received several sound commissions (ABC/The Listening Room, Performance Space) and exhibited work in national and international contexts, including Ars Electronica (*A Rat's Tale*, 2007), the Beijing Biennale of Architecture (*Parametric Flesh*, 2004), the San Francisco MoMA (*iSong*, 2003) and Enter3, Prague (*Rebreathe*, 2007). She has been an invited panelist at the Whitney Museum, an invited speaker for Upgrade! at Eyebeam, NYC and presented work at numerous national and international art events and conferences.

Chapple's writing and art projects have been published in Leonardo Journal, Aminima, *Art of the Biotech Era* (M. Pandilovski ed.) and *Plastic Green* (P. Ednie-Brown ed.). She holds a Masters in Design from RMIT University and is currently working towards an MFA in Art Practice at Stanford University.

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art in the age of nanotechnology

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