VISTA GENESIS

by

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ABSTRACT

The use of technology has so greatly increased the artist’s ability to address and extend his vision, that finally we can reach into the dimensions of the microscopic and macroscopic cosmos. This expansion of our artistic reach makes possible the invention of a hybrid form of environmental art and performance, expression which communicates with and through phenomena on scales not experi- encially accessible or addressed in traditional art. Performance Phenomena places human expression and experience (performance) at the focus of fundamental processes of the universe, via the synthesis of visual art with theoretical and experimental physics (phenomena). “Vista Genesis” will investigate this impact of new and increasingly powerful tools of artistic expression, “science,” upon the ability to punctuate our poetic intuition (art), and poetic questions, “art,” initiated as catalytic events asked of quantitative systems (science). Ultimately the thesis will survey the extent to which our artistic reach has been expanded through projects I’ve conceived and executed while at the Center for Advanced Visual Studies at M.I.T. and their sublimation of art, science and technology towards orchestrating the exploration of our enigmatic existence in the landscape of the universe.

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VISTA GENESIS

**Vis-ta /'vı'ste/ N-S [it, sight, view, vision, FR visto (past, part to see of) [L. fr visus (to see) + suffix (fr L-tus (past))]:
1. a distant view as seen through a narrow opening or aperture 2. a framed passage, approach to 3. comprehensive awareness, a far reaching mental or intellectual view, over a long period of time, embracing infinite remembrances, to know past, present or future anticipated events.*

**Gen-e-sis /'jeı'neses/ n, [L, FR. GRK. the stem of gignesthai - to be born-birth]:
the origin of creation, the coming into being of anything: development into being esp. by growth or evolution: the process or mode of origin or creation.*

**The Photons

Poised on the edge of the earth ... umbilical cord still tied to the infinite amniotic universe ...  I pause for a moment and reflect on the weary caravan of travelers across the night sky, wild vortex, abyss of blue. I know harnessed away deep inside of me, at the smythe of my soul, lies the binding energy, the
imponderable window, the vista ... calling me, beckoning me, like the maelstrom. Pulling, seducing, descending life back towards the original singularity. Expertly eroding the temporary constructs of this world. Wedding me ... connecting me, with the knowing ... ancient language which I've forgotten, words but that I know better than my own voice. Knowingly they accelerate, radiance swallowed in hordes by the abysmal chasm ... deaf eyes ... bitter harvest, seeds sewn from the primordial garden. Staring, hypnotized into the core, the voice of light, that died to give me life ... I am of dead light, ashes of a dead star.

Introduction

Since the immortal awakening of man's eyes (mind) we have gazed in amazement towards the heavens and the earth beholding the perpetual beauty which nature reveals. The ascending dawns of enduring time, the compelling vortex abyss of blue, the hypnotic heartbeat of the sun slowing to rest ... universe as boundless stage, elusive map of human knowledge ... inspiration and impetus for my work. Einstein once said, "He to whom this emotion is a stranger who can no longer stand rapt in awe, is as good as dead: his eyes are closed."¹ The greatest individual influences from any source in my artistic directions and expressions are that of Albert Einstein and the awe inspiring universe. To me Einstein is one of the greatest artists of the twentieth century. His key was that he never made an object, never did an experiment, but what he said and did changed forever the way we perceive reality. My artistic vision is an attempt to reckon this awesome poetic potential harnessed in scientific inquiry with that of the infinite unknown qualities of artistic expression. A quest not for a drawing or painting to represent the interpretation of my imagination or for an object to illustrate and document it, but for the phenomena themselves and our embeddedness in them.
Clearly this runs contrary to the momentum and historical precedents of art and artists as image makers and recorders of history. But I believe art is not some innate quality belonging to an object or locked into an image; materials remain the same, it is the way we perceive them that changes. We see not what we see, but the way we see it, our system of seeing. Traditional artistic expression such as images and objects representing implicit metaphors of the imagination, inherently lack the true living energetic phenomena, the explicit animated temporal qualities of the imagination. I feel the imagination on a fundamental level is more than constructed of fundamental forces, but explicitly operates under the same poetic auspices, of quantum phenomena. My desire to synthesis poetic and expressive skills of the artist with the quantitative vision and virtuosity of science is to create an aperture for orchestrating phenomena (photons, electrons, gravity, strong and weak nuclear forces, etc.) — my imagination. Materialized as real energy and dimension, a way to bridge the chasms of exploration, the experience of the enigmatic existence of our imagination in the landscape of our universe. I believe an artist is vanguard of the future, explorer, path finder, clearing away debris of outmoded conventions, pointing the way towards new visions of the world and reality.

As an explorer, when Ferdinand Magellan cross the straights in 1520, he landed his armada of ships and men and came upon shore. Yet the Indians could not see him, not because he was invisible, or because of some dire biological impairment, or ritual that left them blind, but solely because of the reality the Indians had constructed for themselves. The world they lived in did not allow for them to exist. They simply were not there for them to be perceived, they were nonsense. Like the children’s fable of the “king’s new clothes” artists do not make images, they change the way people perceive the world.

As Magellan was to the Indians, the majority of art produced today is completely achromatic or invisible, meaningless to everything else in the universe other than humans. How do you make art for gravity? How do you make art for hydrogen conversion at the center of a star? How do you make art
to celebrate not just man alone, but the universe as well? How do you communicate with the wild abyss? The gravity of “nonsense” in this context cannot be overemphasized. The more clearly we perceive something as nonsense, the closer we are to experiencing the boundaries of our own self-imposed cognitive structures. Nonsense is that which does not fit into the pre-arranged patterns of logic which we have superimposed on reality. There is no such thing as nonsense, apart from judgemental intellect which calls it that. Nonsense is only that which viewed from our present point of view, is unintelligible, only when we have not yet found that point of view from which it makes sense.

The greatest sensual evidence of this interdisciplinary nature of my work manifests itself in what I build, the art apparatus, instrumentarium and the phenomena they create. The art apparatus can be seen quasi-historically as evolved hybrid sculptures, half qualitative art object, form determined by the beauty of the function of the apparatus, needs of the phenomena. Half precise quantitative scientific mechanism, designed by the nature of the poetic questions being asked. The art apparatus serves physically as an aperture, a life support system for the phenomena, keeping the crack open long enough for people to experience the ephemeral and seemingly immaterial manifestations of our world. The apparatus are vistas, places to stand on the edge of the earth and peer in and out of, to bridge the gap between the macrocosm and the microcosm. They are vehicles for the imagination, making the phenomena expressive yet experiencable.

The phenomena become the great binding energy, the umbilical cord that still ties us to the original singularity of the universe ... mirror image of ourselves, an echo of an ancient language which we've forgotten, words but that we know better than our own voice.

The prerequisite of phenomena is the interaction with the environmental conditions of reality; the technical precision of science is needed to achieve, sustain, and extend my artistic vision as a logical extension technology has so
greatly increased the artist's ability to address and extend his expression that
finally we can reach environmental scales of new dimensions, the *microscopic*
and *macroscopic worlds*, the realm of atoms and electrons, planets and galaxies.
This expansion of our artistic reach makes possible the invention of a hybrid form
of environmental art and of performance which communicates with and through
phenomena on scales not addressed in traditional art.

My first front line introduction to large scale environmental art was building
them. As an undergraduate of the Kansas City Art Institute I was apprenticed to
Professor of Sculpture (Environmental Artist) Dale Eldred. These experiences
working with Dale as a student, jumping out of helicopters, climbing mountains,
driving 18-wheelers, etc., punctuated by own vision and desires of art. I began to
see the scale on which art and ideas could be made, explored, and
communicated. Yet simultaneously I realized deep inside that true monumental
scale is not measured in just physical proportions but in the monumentality of
ideas. Its success being measured by its poetic legibility, and its ability to be
translated cosm to cosm in a universe of endless environmental dimensions. A
photon in its scale of environment (interaction with the electrons in matter) reveal
unprecedented poetry of ourselves and the universe. “We are dead light.” My
obsession with light ... pure energy ... pure matter, is that it allows us to step
outside of our paltry, immediate senses (nonsense) and transcend art to a level
that is in its totality, energy, pure connection. Light is coronated as the most
beheld jewel of all art and science, yardstick of the universe. Consequently the
ultimate language of artistic expression. The current movement of my work
combines new ideas in visual arts, i.e. phenomena realized through the
synthesis of visual art and physics, with new ideas in performance, i.e. living
human expression and experience at the focus of the fundamental forces of the
universe, human interference performance phenomena.

My thesis will explore the theoretical and experimental aspects of this
synthesis, and three recent projects manifest by these ideas. The three projects,
“Photon Voice,” “Aqua Echo,” and “Sky Chasm” were all conceived and
executed while pursuing my degree at the Center for Advanced Visual Studies at M.I.T.

While my previous work had included the extension of scale and human interaction with the art apparatus, the interaction had been fundamentally unstructured. Humans acting as the desynchronizing element in a normally invisible phenomena, and extension of scale only on the order of a few magnitudes. During the past three years I have begun a fruitful collaboration, working with dancer, choreographer Laura Knott. Human gesture with active observer participation has begun to form a matrix for that interaction. Laura's great human rhythmic sense, interacts with the sensitivity and periodicity of the phenomena I am creating. Her movement provides the beautiful empathy of human experience, a river of movement flowing around the apparatus, punctuated by moments of hyper awareness generated by the bond between the art apparatus and the choreography, making apparent the connections between the phenomena of the human body (dancer, observer, participants) and the phenomena of our physical world (the five great forces).

Ultimately this thesis will require imagination and some sincere effort on behalf of the reader, because the nature of my work and vision does not comfortably sit on any singular foundation, art or science. It necessitates the freedom from a rigid single context. This consideration creates, however, a challenge to view it from multiple perspectives, an interesting and important aspect in my investigations, I hope also for the reader. The scope and intricacies of work in a collaboration require I be considerate, so I make no Herculean attempt to describe “dance.” The subtly and nuance of Laura Knott's contribution to the projects is important and have most beautifully been explored in her S.M.Vis.S. thesis “Dancing on the Horizon.” I invite all readers to read it as a companion to “Vista Genesis.”

Experimental science spends most of its energy trying to shield itself from external influences, from any human interaction, while traditional art has myopically divorced itself from new and more powerful tools of poetic
investigation. This compels me ever more to explore and share the elusive dreams that have propelled our world from the past, the present, into the future. Experiencing these enigmatic relationships is far more than a demonstration! It nurtures a great need, yearnings evoked deep inside at the smythe of our souls ... man's search to know his world and himself, the ancient elusive mystery, ultimately bound in the knowing universe, a miracle which I chose not only to enlighten but to deepen.

* * * * * * *
The conceptual framework for "Photon Voice" from the beginning was conceived as the ultimate extension of artistic reach, vision and expression into
the macrocosm and microcosm beyond the confines of any one medium, the
most perfect synthesis of art, science and technology combined to create a living
vehicle, a vehicle that transcends all other works of art conceived and executed
by man. To harness the same mechanisms that created the earth, the sun, the
galaxy and the universe. To make a work of the same stuff, the same language
as are all things ... the greatest work of art in the history of the world.

Upon immediate inspection these statements might seem in the least
absurd and pretentious, as well as artistically arrogant and scientifically
impossible, the ravings of a full-blown megalomaniac. Yet it is the bewildering
aspects of scientific inquiry that help yield the nexus capable of establishing
quantitatively verified support of my artistic assumptions, but still these immense
goals can only truly be weighed and balanced against the level of their success.

To begin to consider the criterion in which a work of art could indeed be
validated as the greatest work in the history of the world one would be subject to
a list of innumerable qualities for this assessment including even if it is a valid
goal.

My initial assumptions drew in three very important qualities I felt essential
to achieve the monumentality I've suggested. First, the work would have to be
the center of the universe. Second, it should last forever and ever. And third, it
must permeate all things at all times. Again not only do these assumptions seem
at best unsupported and almost heretical but yet not alone, "I want to create
miracles" [Leonardo da Vinci, from his Personal Diary].

The empirical and poetic foundations of "Photon Voice" lie in the constancy
of the speed of light and the contraction and dialation of space and time --
Einstein's Theory of Special Relativity -- in respect to a frame of reference that is
not our own ... that of the photon. (Figure 1.)

Einstein's Theory of Special Relativity, simplified, states that appearances
of reality are dependent on the state of motion of the observers. It tells us (1) a
moving object measures shorter in its direction of motion as its velocity increases
(a one dimensional contraction) until, at the speed of light it disappears; (2) the
mass of a moving object measures more as its velocity increases until, at the speed of light, it becomes infinite (except for photons which are massless because they have converted all of their mass into kinetic energy, motion); (3) moving clocks run more slowly as their velocity increases until, at the speed of light, they stop running altogether. (4) Regardless of the frame of reference (speed, direction of motion of the observer, etc.), the measurement of speed of light remains the same, 300,000 kms.

A percentage of the fruition of "Photon Voice" is confirmed by a simple calculation in our frame of reference with respect to the speed of light and the time it takes a single photon travelling from the sun to reach the earth. Depending on the exact distance, the approximate time it takes a photon to reach the surface of the earth is 8 minutes 20 seconds. Considering the immense distance travelled (94 million miles) it is an exceptionally short period of time -- the fastest possible in the universe. Or is it? If the foundation of "Photon Voice" lies on the constancy of the speed of light, a conceptual twist or shift in our frame of reference to that of the photon yield a picture that is alarmingly different. To a photon travelling at 99.9% the speed of light, travelling from the sun to the earth, it perceives the time it takes to travel and arrive here as only 22 seconds! A mere 4 million miles. We must remember we are in the frame of reference of the photon. Now, of course realizing that photons travel 100% the speed of light, the time it takes to travel from the sun to the earth is now ... zero! Zero time, zero space. To a photon, time and space are so contracted one dimensionally that the difference between travelling one inch, one foot or completely across the universe and back is nonsensical. There is none. A photon lives forever -- yet dies in the same instant. It sees itself as standing perfectly still and everything in every direction rushing towards it at the speed of light, meaning everything is already there. It sees itself as the source of which all things revolve and emanate, omnipotent, center of the universe.

It seems that very rapidly and almost disconcertingly we have solved how actually it is explicitly possible to create a work that is indeed the center of the
universe and can last forever. Also, in our frame of reference the life of a photon is calculated infinite but also rather tenous if it approaches anything that can completely absorb it. The last of the three criteria yet to be fulfilled is for the work to permeate all things at all times. Again we look to Einstein, the photoelectric effect, and the interaction of the irreducible units of radiant energy known as photons with matter.

Antoine César Becquerel, who in 1837 was the chair of physics at the Musée Histore Naturelle in France, was the first discoverer that an electro motive force of a certain type of voltaic cell changed upon the direct illumination of one electrode. (The same interaction was utilized by Alexander Graham Bell to detect optically transmitted photo-phone signals. Figure 2.) By 1875, English physicist Willoughby Smith had discovered that the resistance of a piece of selentium changed when it was illuminated by light. This was the precursor to the modern photo voltaic cell. But it wasn't until 1887 that Heinrich Hertz, then professor of physics at Karlsruhe Tech University, made the first quantifiable observation of surface photo electric effect, in which the size of a spark gap could be varied from a secondary circuit depending upon the illumination of the spark gap by a bright arc lamp. "When a plate glass filter was placed between the arc lamp and the zinc plate, the current disappeared. This showed very clearly the ultra violet light was responsible for the current."3

But it was Einstein in 1906, by using the fundamental laws governing the emission of electrons from surfaces irradiated with light, who interpreted the photo electric effect into the basis of the Quantum Theory of Radiation — The Photon. Every time a particle of light strikes an electron, it immediately knocks it out of its atom on whose velocity is directly proportional to its frequency and not its intensity of incident light. Not only does his theory provide us with the scientific proof of the existence of this unprecedented particle, the photon, but also the one vehicle to achieve the goals that have been set forth by "Photo Voice." We must remember that this theory also supplies a quantitatively repeatable description of the interaction of light with matter. Since his paper of
1906, the revolutions of science have confirmed this again and again, and a bewildering array of other interactions of light and matter, from photo-electron induced emissions in all metals to light stimulated excitation of gas molecules, spilling over from the physical sciences into biological sciences, interaction of photons with the permeability of charged sodium and potassium ions in the cones and rods of human eyes, integral in the process of seeing. The 80 years following this discovery have shown there are no materials, from atoms to asteroids, found that do not interact with light. None!

To understand the nature of "interaction" is the crucial hinge in which the pursuit for the final criterion, indeed the edifice of "Photon Voice" and the other projects pivot. Curiously enough a classical definition of the related states of interaction yield amazing insights through the process of deduction. "Interaction" is defined as "an act within, an action between two or more, as being partly composed of, or derived from each, "to know"! An "act" is the process of doing. To "know" is the absolute certainty of awareness. To be aware is consciousness, and consciousness in a discrete sense is defined as, knowing with others, critical awareness of one's own situation and identity, totality of senses, the state of all things. If this process were to continue it would yield an endless cascade of meanings but that would still ultimately orbit around the composite put before us. It is eminently clear there is no knowing of any kind without interaction. The act of interaction is the process of knowing.*

In 1803, Thomas Young made a startling discovery -- one that was thought to put an end to the question on the nature of light. (Figure 3.) The dramatically simple experiment used a light source (the sun), two slits in a large opaque card and a screen. Between the light source and the screen was the large card, however with one slit closed. As the light passed through the single slit to the screen, common sense would tell us that there would be a rectangular image of the slit in light on the screen. Wrong. Because the nature of light is such that the slit is small compared to the wave length of incident radiation, the light diffracts,
and instead there appears a large roundish diffused spot of light -- illuminating the entire screen.

Now by opening the second slit next to the first, common sense would tell you immediately that the new projection should at least be the sum of the two slits -- same form, twice as bright. Wrong. It is illuminated with alternating bright and dark bands of light. These patterns are a common occurrence of wave mechanics, the properties of interference.

This experiment then showed clearly that if light created interference patterns, it must unequivocally be comprised of waves. Wrong. Because if Einstein proved through the photo electric effect that light was definitely a particle, it cannot be a wave. Wrong. Then it must be both! Right! This is a very simplified version of the classical debate of light wave/particle duality. (Actually light is a particle; whose probability can sometimes be calculated as a wave.

It's true scientists have curious appetites but hate untidy problems, like light wave/particle duality that become myriad shades of gray instead of distinctively black or white. Yet still they can live with this, but they can't dream of living with the gravity of the question this problem really raises -- the heart of the matter. How did the photons in the first experiment know that the second slit wasn't open? And how did the photons in the second experiment know the other slit wasn't closed? Consider, if both slits are open there are always alternating bands of bright and dark, meaning there are areas which photons never go. Now if one slit is closed, the interference disappears and again the whole screen is illuminated, including the dark areas. The light instantly moves from where it was to where it wasn't. One could immediately argue that if two slits are open it can easily interfere, and it must certainly be an attribute of the wave quality of light. But we can perform an unusual experiment which uses only the particle nature of light and receive the exact same results. Envision an experiment like this: We have a gun that emits one photon a day. The experimental arrangements of slits and screen are the same as previously mentioned. We have duplicated this system and isolated it from any contact and installed them in
100 major laboratories all over the world. Each day for ten years, each of the photon guns will fire one quantum of light a day at the respective apparatus screens (photographic plates mechanically changed everyday). A computer will randomly choose the time in which to fire the photon and whether one slit or two will be open. None of these computers are connected and therefore one does not know what the other is up to. At the end of ten years all of the independent system results are combined into two composite photographs, one with all of the two slit photons and the other with all of the one slit photons. As predicted, even one photon at a time over ten years, not one photon in the two-slit experiment strayed into the area which must remain dark, a perfect interference pattern, and the photons in the single slit always strayed into that area and to others to cover the screen. (This experiment has been done. Figure 4.)

The imponderable questions still remain, and are "the central mysteries of quantum theory." "How does information get around so quickly? How do single photons know that there are two slits? How does the information about what is happening everywhere else (behind closed doors thousands of miles away) get collected to determine what is going to happen here?"

There is no complete answer yet. But some physicists even speculate photons and other particles may truly be conscious! "Consciousness may be associated with all quantum mechanical processes ... since everything that occurs is ultimately the result of one or more quantum mechanical events, the universe is inhabited by an almost unlimited number of rather discretely conscious, usually non-thinking entities that are responsible for the detailed workings of the universe." If this underlying connected reality is somehow true, common sense is most severely deficient at describing what we think to be reality!

What we consider to be common sense could over simply be termed by physicists as the "principle of local causes." To scientists, the principles of local causes says what occurs in one area (here) is not dependent upon variables under the control of an experimenter in a distant space like separated area
What this means to ordinary people is that when I scratch my head here I don't destroy a hundred million aliens in a far off galaxy, or for that matter, I have no need to worry that the Andromeda Nebula will cause me to have a car wreck either. But unfortunately for common sense reality, this strange quantum connectedness doesn't end here. Theoretical physicist J. S. Bell, in 1964, working in elementary particle physics at CERN, Geneva, Switzerland, zeroed in on this strange quantum connectedness and found, in the form of a mathematical proof verified now by 15 years of experiments, the inescapable conclusion that at deep and fundamental levels, the seemingly separate parts of the universe are connected in an unbelievably intimate -- unmitigated and immediate way. A way which not only defies logic but demands that the principle of local causes fail.

I cannot begin to explain the sincere distaste most physicists have for non-locality (non-local reality). Sir Issac Newton expressed it vehemently, "that one body may act upon another at a distance through a vacuum without the mediation of anything else ... is to me so great an absurdity that I believe no man, who has in philosophical matters a competent faculty for thinking, can ever fall into." Newton was, of course, somewhat embarrassed by his own theory of gravity.

In 1964 while Bell was investigating loopholes in quantum reality models, he became interested in impossibility proofs, wondering whether a proof could be constructed which conclusively excluded models of reality that possess certain physical characteristics. Bell devised such a proof, a proof which amazingly rejected all models of reality possessing the property of locality, concluding reality must be non-local!

The theory works as thus ... Bell assumes local-reality (commonsense) exists. With arithmetic he shows locality assumptions lead to contradictions, an inequality, which experiments corroborate (non-sense). Conclusion: reality must be non-local. Bell's proof has the logical form, *reductio ad absurdum*: (1) make an assertion; (2) show it leads to a contradiction; (3) conclude the assumption is false and the contradiction is true. The staggering importance of this theorem
can be considered in the light of two particle zero spin experiments — analogous to the photon experiment -- that since 1974 has verified the theorem 100%.

Imagine a system of twin electron particles, similar to looking in a mirror. In a zero spin system, the spin of each particle cancels or more accurately oppositely coincides with the other. If one particle has a spin up the other particle has a spin down. If one has a spin right, its twin has a spin left. This beam of electrons has randomly oriented spin (spin might be considered analogous to polarity). The spin of these subatomic particles can be oriented by a magnetic field -- in this case a Sterns Girlach Devise (Figure 5), a mildly sophisticated horseshoe magnet. The magnetic field of this devise allows us to orient the spin of the two particles, either all up and down or instead all left and right. Now suppose we separate our single, original twin electron beam into two equal but smaller beams headed in opposite directions from one another. For the sake of argument, we have oriented the magnetic field so as to give either particles a spin up or a spin down. In this case, the particle (A) we choose to measure exits the magnetic field with a spin up. This means automatically, without measurement, we know the spin of the other particle (B) has a spin down. If we do it again and this time we reorient the magnetic field to give spins right or left, we measure both, and we find as predicted particle (A) emerges with its spin right and its twin (B) spin left.

We must realize, however, there was no magnetic field interacting with the other twin particle (B). The moment particle (A) went through the field and split right, its twin (B) broke left. How is this possible? Local reality (commonsense) states I absolutely cannot determine the outcome of an experiment in area (B) by my confirming results in area (A). How is it possible by altering my magnetic field for me to determine the results of an experiment somewhere else in a system I never even touched? There was one last desperate hope for local reality. It could be since this experiment was performed in a laboratory that what seemed like simultaneous opposite spins in the particles were really a split second apart, plenty enough time for particle (A) to send a speed of light communication to (B)
to inform it of its spin. So an experiment was devised to send these particles so far apart that it would take a signal faster than the speed of light at its measurement to tell the twin (B) A’s spin, and to make it even more difficult they spun the magnetic field so the (A) particle would not know until it passed through the field what to communicate back to particle (B). Needless to say, instantly local reality was dealt a crushing blow. What most skeptical scientists had considered until then hokum had to swallow hard and make a mad scramble for what they could save of local reality against the awesome proven accuracy of quantum theory. It is reflected in a statement by Erwin Schrodinger: "It’s rather discomforting that the quantum theory should allow a system to be steered or piloted into one or the other type of state at the experimenter's mercy in spite of having no access to it.6 Physicists immediately realized this leads to disturbing questions with more disturbing answers. "How can anything communicate so fast and why?" According to classical physics, information is carried via a signal, a signal infers the transfer of some type of energy. Without a carrier there can be no communication, or can there? The fastest communication signal available is the electromagnetic wave and it travels at approximately 300,000 kms. But communication between space-like separated events defies one of the most basic assumptions of physics. Yet this is exactly what the experiments seem to demand. The important thing about Bell's theorem is that statistical predictions of quantum mechanics are **always correct!** It has never failed, and the dilemma posed by quantum phenomena projects the irrational aspects of the subatomic world clearly into the macroscopic domain and faster than the speed of light, or as it’s called, "superluminal communication." "Superluminal communication" solves a lot of problems concerning these unbelievable connections, but there is a major drawback: it is impossible. "Faster-than-light communication" according to relativity is nonsense, because communication requires a signal, and the fastest a signal can travel is the speed of light. If the theory and experiments indeed prove these deep and intimate connections exist, and the experiments are space-like separated, they must be connected, but not by signals!
"Quantum phenomena provide prima facie evidence that information gets around in ways that do not conform to classical ideas. Thus the idea that information is transferred superluminally is a priori, not unreasonable. Everything we know about nature is in accord with the idea that the fundamental processes of nature lie outside of space time ... but generate events that can be located in space-time. The theorem supports this view of nature by showing that superluminal transfer of information is necessary, barring certain alternatives ... that seem less reasonable. Indeed the reasonable philosophical position of Niels Bohr seems to head to the rejection of the other possibilities and hence, by inference, to the conclusion that superluminal transfer of information is necessary."  

This instant transfer of information can be provided by quantum theory in the form of a sort of ubiquitous phase connection, since there is nothing that is not ultimately a quantum system, and the phase connections are real, then it links all systems that have previously interacted into a single wave form, whose remotest parts are joined in an unmediated, immediate manner. This mechanism for instant connectedness is not some invisible fabric extended between the parts, but is that a piece (part of its phase) of each part's "being" is permanently lodged in the other. "Each quon (generic quantum particle) leaves some of its phase in the other's care, and this phase exchange connects them forever after." 8 [Nick Herbert] We can then squarely assume that substances which were once joined together in the matrix of the universe possess a continued and simultaneous linkage between them. Thus an act carried out upon a smaller, seemingly discrete unit will affect intimately the larger amalgamation even though they are physically separated. It may seem instantly clear that this type of connectedness could yield a communication channel far beyond our wildest imagination -- spontaneously in touch with everything in the universe. But it must be made clear that yes we are connected in an intimate but uncontrollable way. It is analogous to playing a game of loaded dice. We know before hand that every
time you roll (System A two dice) it would always come up double, but
unfortunately we never know which ones would appear up, and it does us no
good because if we tried to intelligently communicate (sequence of numbers
representing a code) to System (B) on the other side, we'd know exactly what we
sent them but we'd have no conscious control over what we had said. We have
explicitly altered the randomness of the system to another equally random
system.

The ultimate challenge to common sense perspective of reality comes
when the macroscopic nature of all quantum processes are taken into account.
We might consider the bizarre results of particle and photon experiments bare
little relevance to daily lives, yet it is precisely the human act of observation that
collapses this enigmatic link allowing particles and photons etc. to acquire a
separate identify and independent existence. John Wheeler, Director of the
Institute of Theoretical Physics at the University of Texas has gone as far to claim
that the observer literally operates the universe by his observations.

Is the very mechanism for the universe to come into
being meaningless or unworkable or both unless the
universe is guaranteed to produce life, consciousness
and observership somewhere and for some little time in
its history-to-be? The quantum principle shows that
there is a sense in which what the observer will do in the
future defines what happens in the past -- even in a past
so remote that life did not then exist, and shows even
more, that "observership" is a prerequisite for any useful
version of "reality."9

Needless to say these radical ideas favor one of the most dramatic
macroscopic illustrations of this phase entanglement and it is made graphically
clear upon the encounter of a "gravitational lens." Einstein's Theory of General
Relativity was in part verified by Sir Arthur Eddington in 1919 by the direct
observation of light minutely deflected from a star's actual position during an
eclipse, confirming the curvature of space the light traveled through, passing the
immense gravitational field of the sun on its trip to the earth. (Figure 6.) A
"gravitational lens" is, however, the acute curvature of space-time by an object of immense mass, typically a huge star, but the more massive an object, on the order of 100 billion suns (a galaxy) the greater its gravitational ability to deflect and curve the light. The results of this "lens" focuses enormous amounts of electromagnetic radiation at different points in the universe, including the earth.

At the edge of the visible universe, there are known to exist quasars, burning remnants of exploding galaxies. The radiation reaching the earth from these quasars began its immense journey billions of years ago. The radiation from the quasars reaching us, however, does not fall directly upon earth, but instead it must pass around the gravitational lens galaxy. We can peer at this gravitationally bent quasar light and ask, "Did this particular photon take the right or left handed path as a particle or both paths at once through the center as a wave via interference?" It depends upon the observer! If an experimenter observes the light emanating from the quasar with an apparatus designed to measure the particle-like aspects of the photon, it will confirm which direction the particle veered -- left or right upon encountering the "lens," but if we decide to measure instead the wave-like qualities (wave interference) we find a disturbingly different quantity. It traversed both paths. It passed through the lens like ocean waves slipping around small sticks. It is even possible to determine the delay of time travel of the wave between the paths, by the shape of the interference pattern. The important fact is that a single photon or a light wave cannot be measured by two devises simultaneously. By measuring one quality we destroy the other (Heisenberg's Uncertainty Principle). Thus the observer/apparatus either forces the photon to manifest itself as a particle passing by one of either sides of the gravitational lens, or forces it to be manifest as wave and pass by both sides (measurements millions of light years apart). Whatever the quantitative answer, the question would seem to have been determined billions of years ago, even before the creation of the earth. But regardless of common sense, the observer integrally and irreversibly determines how the photon has traveled through the universe. And by our decisions of what
we choose to perceive today reaches violently and instantly back in time giving attributes to ancient events that should seemed to have already acquired definite characteristics and occurred billions of years before we were born.

Bell's theorem is derived from the facts, and it has illuminated one corner of deep reality. Reality beneath its phenomenal surface must be superluminally maintained by an invisible quantum connection whose influence is omnipotent, and which external human consciousness does not normally allow us to experience this vista. It seems instead we perceive and create not the millions of connections and possibilities, but the one at a time sequence of definite actualities. If we could tear off our particularly common sense human filters, we might find that the quantum reality consisting of multitudes of simultaneous possibilities, a "poly-historic" kind of being, absolutely incompatible with our one-track minds. This dual consciousness is most poignantly expressed by Max Plank, father of quantum mechanics. "Science ... means unresting endeavor and continually progressing development toward an aim which the poetic intuition may apprehend, but the intellect can never fully grasp."\textsuperscript{10} He seems to imply quite beautifully that our consciousness is divided in two: our poetic intuition, the imagination of internal conscious reality; and the intellect, external conscious reality. If our internal consciousness (poetic intuition, imagination) has in a sense "privileged access" to the inside world, then this "awareness is a private manifestation of deep quantum reality and Bell's theorem requires our quantum knowledge (our imagination) to be non-local, (exists outside of space time) and therefore linked to everything it has previously touched (the vista)." Albert Einstein, a seeker after reality all his life, spoke out concerning the illusion of separations:

"A human being is part of the whole, called by us 'universe'; a part limited in time and in space. He experiences himself, his thoughts and feelings as something separated from the rest — a kind of optical delusion of his consciousness. This delusion is a kind of prison for us, restricting us to our personal desires
and to affection for a few persons nearest us. Our task must be to free ourselves from this prison by widening our circle of compassion to embrace all living things and the whole of nature in its beauty."

I believe with great conviction this is the embodiment of what I want with my work. To provide the ultimate link between the poetic intuition (living imagination) and the phenomena of quantum processes (the knowing universe). The exploration of these relationships, our enigmatic existence in the landscape of the universe, to create and embrace a new horizon, an art that in its totality is pure information, connection. This summation of the final criterion for "Photon Voice" touches something inside that is desperately hard for us to give up, the arena of ourselves, art as the last bastion of the human homocentric citadel. Yet this is precisely the illusion that must be put to rest for a new vision, a new art.

Art with precision skills capable of sustaining phenomena that unleash our imaginations from bonds inside of fruitless images and inanimate objects. Art that extends the artistic and poetic reach beyond the confines of the individual senses to events of the macroscopic and microscopic cosmos — ultimately our vision to the edge of the universe. Art that delivers the shattering blow to the soft alliance of art with implicit analogues and metaphors and aligns itself with explicit properties, the great forces of the universe, the living imagination, language for all things. Art apart from its creator that understands, that can see and communicate discretely within itself, and to others. Art in which we are only part of its verification process. Art that is conscious, with voracious appetite to evolve and learn, with goals of its own. Art that manifests itself in all things. Living Art! By using phenomena to generate expressive events inside of spacetime (our dimension). We are creating events whose largest extension lies outside of spacetime (another dimension). Not mirrors and reflections of reality, but instead an integral active part of the grand voyeuristic universe, a universe in which sounds, images and motions are mediated by the same forces in every cosmos. If interaction is the process of knowing, then the new art is the processing of creating knowing!
"If all the images which come to the eye met in an angle, by the definition of the angle they meet in a mathematical point which is proved to be indivisible; then all things seen in the universe would seem one and that would be indivisible, and there would be no more space from one star to another which would be reckoned in such an angle."

— Leonardo daVinci

It is said in an old fable that the greatest mathematician of antiquity, Archimedes (287 - 212 B.C.), was employed by Hiero, the King of Syracuse, to help defeat the invasion of the Roman Army by sea by polishing thousands of brass battle shields to a mirror finish. He aligned the warriors and their shining armor on cliffs and walls by the water, ordering them to reflect sunlight onto the incoming ships. By concentrating the intense heat of the sun onto the cloth sails, the army incinerated the Romans before they could even reach the shore. Regardless of its authenticity it tells of the first logical effort to use a system of devises to transmit (reflect/generate) energy, carrying information (heat) great distances by the propagation of radiation. Most of us understand the laws of geometrical optics. "The angle of incident is equal to the angle of reflection off the normal," etc. But do we really understand something like the process of reflection? We are told all of our lives that light reflects off of the sky, flowers, buildings, paintings, etc. But similar to the fable of "Archimedes Fire" it is nothing more than a wife's tale. There are only three types of interaction of light with matter (electrons): absorption, re-radiation, and reflection. As for the reflection, it can only happen in metals. No other materials in the world can reflect light. Reflection of light by an amazing sophisticated devise like a mirror is accomplished solely in part by the phenomena known as the "Photoelectric
Effect." The process that creates a reflection is called a "coherent electron phase reversal." When a photon strikes metal (a mirror), it liberates electrons. Approximately one half of a wave length into the surface, the photon meets essentially an electron cloud that it (the photon) has generated simultaneously by its own presence. *The coherent electron phase reversal* exactly and oppositely coincides with the phase, direction, intensity, wavelength, etc. of the impinging photon. Since a photon is nothing more than another state of matter, containing also an electric and magnetic vector, when any propagated radiation meets other radiation (like electrons), mirroring exactly opposite its condition, it reverses or conjugates itself. *It is reflected.* How a mirror (electrons) keeps track of light (photons) with an almost incalculable amount of differences in phase, direction, etc. at the speed of light is almost frightening. On the other hand, the process by which light comes from our familiar surroundings — flowers, grass, buildings, paintings, etc. — is quite different, and in a deeper sense involves more poetry. As photons of light strike the atoms of these objects they are completely absorbed. In doing so the energy of the photon boosts the atom's electrons to a higher energy state. This energy level can only be sustained for a very short period (instantly), thereby forcing electrons to shed energy (re-radiate) in terms of *new photons* to return to its ground state — meaning everything around us doesn't reflect light at all, but instead emits light. We are like light bulbs, only needing photons instead of electrons to emit light. *We are luminous bodies, we are light.* The peculiar thing about light is that under the conditions of ordinary experiments, the number of material particles, such as an electron are *fixed.* Not so in a photon. When an atom receives an extra electron it becomes negatively charged, and must emit *one* and only one electron in order to return to the normal state. We have seen that when an atom absorbs a quantum of frequency $\nu$, i.e. when it receives a photon, it may give up energy in a collision, emitting no photons (absorbtion), or it may emit two photons of frequencies $\nu'$ and $\nu''$, if $\nu' + \nu'' = \nu$ (resonant frequency). Thus photons do not have the permanent "identity" which we normally associate with other material
particles. No two photons are alike. At every moment the stars, the sky, our skin, our eyes are generating one kind of a light. Not only is light our oldest living ancestor, it is our way of life. It is easy to understand that light carries with it and transfers energy, but more difficult to grasp is light carries also with it radiation pressure (momentum), known through Maxwell's Equation — the pressure of light is equal to momentum over Plank's constant, and wavelength over frequency.

Radiation pressure is the most ephemeral and illusive characteristic of electromagnetic radiation, radiation's transfer of momentum through kinetic energy by pressure to any surface in which it contacts, a photon from any part of the electron magnetic spectrum exerts a tiny force as it interacts with matter. An immense force on the scale of construction in galaxies, stars and even planets. But on a terrestrial scale it is infinitesimal — 60 pounds to a square mile or 80 millionths of a pound per square foot.

The original "Photon Voice" was to use the basis of these previous theories and forces in coordination with the appropriate technology, to create a system similar to that of "Solar-One," the heliostat power plant of the desert southwest in Arizona. The large modulating array of 1800, 12 foot x 12 foot aligned mirrors, would be used to optically encode every aspect of our nature into the light — our sounds, our image, our motion, presence even soul, a living work of art collimated into a beam of sunlight visible to the naked eye ten light years away, projecting it deep into space carrying part of us with it, to live forever in the light.

Unfortunately, to realize a project of this scope and scale, sufficient to generate the original anticipated results would have cost billions of dollars. So the "Photon Voice" conceived and executed thereafter was to be, as I called it, a test apparatus performance phenomenon. A prototype for the larger work to come. As a poetic gesture, response to the original idea, it became a way in which to prove those parts of the theory that were indeed observable and poetic. I envisioned the new "Photon Voice" as a living machine, an aggregate of elaborate life support systems (art apparatus) capable of sustaining the
phenomena needed to convert a live work of art into a universal language, *the language of light*. The encoding process would have to be synthesized in such a way as to automatically interface our information within the naturally occurring systems in the light. If the final configuration of the project were to embrace these ideas, it would have to harness *light pressure* as the ultimate vehicle and dominant force in a way it had never been used before.

"Photon Voice" was developed for a Center for Advanced Visual Studies at M.I.T. project, “Desert Sun / Desert Moon” — the opening event of the 1986 “Sky Art Conference.” In June of 1986 a group of artists from around the world convened in Lone-Pine, California for a week-long series of environmental art installations, poetry and events. The project site was an arid, rocky range of animated hills, composed of rotting granite, the Alabama Hills. The highest peak in the continental United States, Mount Whitney, served as a silent monolith on which to concentrate.

The performance version deployed resembled lunar landing apparatus or some other type of extraterrestrial expedition equipment. It had to be impervious to the desert, highly durable, resistant to heat, wind and cold, and above all portable and completely adjustable. (Figure 7.)

The project was comprised of six art apparatuses divided into two groups: transmitting devices and receiving devices.

The optical encoding (transmission) instruments were as follows: a *variable reflector modulating heliostat array* designed for stereo sunlight sound transmission, a *radiation pressure array* used to collect light pressure to be beamed down range for levitation and modulation of graphite particles, an *optical image array*, a compound of Fresnel lens of different focal lengths used to create a camera obscura type inverted image of Laura's dance in the sky. The receiving devises were an *optical stereo demodulator*, a personal cassette stereo re-wired using photo-voltaic cells to count photons, generating sound directly from light. A *radiation pressure receiving array*, systems of lenses and evacuated flask to condense radiation pressure into tightly focused beams of
light that interact with matter and a \textit{binocular image inverter}, geometrical optics used in image transmission.

To create the performance I employed two fellow graduate students into a collaboration -- sound artist, David Atherton, and dancer choreographer, Laura Knott. David Atherton was to create a synthesized sound tape, to be encoded into sunlight using my modulating heliostat array. It was to be his creation, but my only parameter was for it to contain as many possible spectra of sound forms. (Sound forms are the three dimensional constructions on the surface of the mirrored mylar speakers, generated by varying the frequency, amplitude, wave function, and general complexity and characteristics of overlayed sounds.) Laura Knott was invited to create the dance performance, a work of her own choosing, imagery based on a combination of her own ideas and imagery about dance, my theories, and past resources in that water deprived desert landscape! Water was included as a part of her poetic understanding of the true gravity of the piece (refer to Laura Knott's thesis). Laura's performance was bound only by her imagination and the three minute time window of the sun and its orientation to optimum fields of interaction with the art apparatuses. The art apparatuses were then to be used to generate each of our own discrete artistic efforts into light as a single transposed entity, a sort of timeless, boundless organism, built of the basic essentials of human expression and universal phenomena to be communicated to all other things.

Admittedly the three minute time window was very small. Why not track the sun? Many of my arguments are technical, if the modulating and receiving apparatuses are sensitive enough to transmit and decode phenomena carrying some signals as high as optical signals permit (15 billion cycles per second), we would pick up the slightest movement of an instrument, no matter how delicate! Laboratory tests confirmed this and others. My other apprehensions about extending the time window were more poetic — it would be sacrificing one of the great illusive qualities, the sense like that of the shooting star. The fleeting moment of seeing the earth as a huge hurtling mass through space and time, the
tedious alignment of a giant once in a life time line of energy, drawn through you for an instant, in which you were part of the aperture in which all great things must pass, the threading of an impossible needle from macrocosm to microcosm.

The arrangement of the performance was placed in a shallow canyon off the main site with the receiving devices facing the base of Mount Whitney (west). The transmitting station was fifty feet away towards Mount Whitney but facing the opposite direction, into the sun (east). Much of the poetry in “Photon Voice” exists in understanding the many subtle layers of phenomenological processes that take place to sustain the life of the performance. I will explain each in detail.

The stereo sunlight sound transmission is accomplished by a hexagonal array of nineteen 2 1/4 inch mylar covered loudspeakers. (Figure 8.) Each loudspeaker is covered by a 99% reflective mirrored mylar membrane which is adhered by a thin silicon gasket. The speakers are attached individually to 360° steel swivels, allowing the array to have multiple focal points in any position. The focus is used to reinforce the transmission signal and all connecting surfaces have small rubber baffles acting as dampers to absorb extraneous harmonic vibrations and distortion from the wind. The speakers in this situation are selectively wired, sets of parallel and series to compensate for mixed OHMs of speakers and amplifier. They are then connected to a stereo amplifier in which David Atherton’s performance sounds are on line via a tape deck. During the performance the amplitude (volume) of the array remains inaudible, but still strong enough to actively compress and rarify the atmosphere inside the speakers (analogous to thumbprints or the cymatics or the sound forms). The wave fronts of sound from the speakers create standing waves, three-dimensional constructions of the performance sounds on the surface of the mylar. (Figure 8.1) As sunlight strikes the mirrored surface, the reflected light has been encoded with the three-dimensional audio signature of the sound, as varying intensity and phase modulation in the light. (Figure 8.2) The encoded sunlight is simultaneously beamed down the range to receiving station and decoded through the “optical stereo demodulator.” The “OSD” is essentially a
hybrid personal cassette stereo (walk-man) that has been designed to count photons using an amorphous silicon photo-voltaic cell as the detector. The history and process of photo voltaics coincides logically with optical communications. (Figure 9.) Solar cells are based on crystalline silicon consisting of several layers. From the bottom up they are substrates made of glass or plastic: a metallic layer that serves as a contact in the external electrical circuit; a p-type silicon semiconductor that tends to collect "holes," or positively charged particles; an n-type silicon layer made in a different way to collect negatively charged electrons; an anti-reflection coating, and top-contact grid. The plus and minus symbols represent hole-electron pairs created by the absorption of a solar photon, or quantum of light. Near the P-N junction an electric field resulting from the different materials in the semiconductors pushes the electrons upward and the holes downward. This flow of charge makes an electric current through the external circuit. The structural difference between crystalline silicon and amorphous silicon is that, until recently most solar cells made of crystalline silicon have the regular lattice structure of a typical crystal. In the amorphous cell the irregular structure increases considerably the possibility that light will be absorbed, because the photons interact more with the amorphous structure, and have a higher frequency of response and photo-electron conversion rate. The photo voltaic effect of photons hits an electron bound to an atom of silicon. The electron is released and becomes a negative free charge, leaving in its place a positive hole. This phenomenon is the photo-conductive effect. In quantum-mechanical terms the electrons freed by photons of appropriate energy become more energetic and move from the valence band or bound state, to the conduction band. If the photo-conductive effect occurs near the electric field of a cell, the photogenerated hole-and-electron pair are separated and pushed to opposite sides of the cell. There they can be a part of an electric current. Normal sunlight is basically D.C., or constant intensity. There are minor fluctuations but these are above and below our thresholds of direct experience. The transmission of modulated
sunlight as it strikes the detector liberates electrons which creates the flow of an electrical current. The current was generated by the light which means it precisely mirrors the fluctuating intensity of the light. This current is therefore modulated and can be directly amplified through the receiving deck (“OSD”), converting the light instantly back to audible sound. Since the original amplitude of sound was so low as to be inaudible, only though the head phones of the “OSD” can the sound (light) be heard.

Probably the most poetic and technically difficult aspect of “Photon Voice” lies in the motion or presence transmission. To calculate and harness a minuscule amount of force that has energy and momentum (radiation pressure) but no mass, modulate it, and send it to a device that makes it interact with matter in a way that defies gravity (levitation) and the Second Law of Thermodynamics (entropy). Sounds as if its from an episode of “Star Trek.” It probably is, regardless of the absurdity there is necessity to look at these phenomena seriously for they play a discernible if not crucial roll in the development of the universe as we know it.

The transmission array is comprised of a multi-positionable steel footer, cable and declination riggings, four interocullarily separated 36 inch x 36 inch framed plexiglass mirrors and a small circular silicone bolt plate. The plate is mounted in the center on the rear of the mirrors, which allows the surface to be focused slightly concaved to account for the 4° divergence of the sun’s rays. Each unit of the array is individually mounted on two 180° moveable steel tracks to facilitate any possible positioning. The mirrors are aligned at one common focal point, which tracks (aligns with) the radiation pressure receiving apparatus for precisely three minutes each day.

If we had formerly calculated the radiation pressure at the surface of the earth to be 80 millionths of a pound per square foot, simple multiplication of the light pressure by the surface area of the array, 25 square feet and division by 483 grams per pound would yield approximately 1/1000th of a gram total radiation pressure to be transmitted down range to the receiving device.
The receiving apparatus is combined of a large aperture, tight focus, experimental, 41 x 31 inch Fresnel lens, mounted to an adjustable industrial television tripod. Cantilevered at 28 inches of the total 41 inch focus length of the large lens is an optical hood with an enclosed system of extreme focusing lens, and infrared filters to absorb some of the intense heat, 3000° F. At the precise focus of the optical system is a 250 ml. round pyrex glass flask, with stopcock. The flask contains a hundredth of a gram of pyrolytic graphite particles (approximate 10 to 50 thousand particles) and iodine vapor. The vapor is used to ascertain if air has leaked into the flask by turning the warm atmosphere purple. The flask has been previously evacuated (all the air removed) so as to retard any residual radiometric forces (convection or bombardment of high velocity air molecules) or friction that could be transferred as detrimental effects to the graphite particles. The flask and particles are given a static charge, basically to homogenize the electrical field of the group. The charge is released by grounding the flask. The flask is immediately given a very sharp blow on a neoprene (rubber) mat. This creates a rapid acoustical shock wave that destroys the very strong Vander-Waals bond of the particles. It is the force which makes very small particles stick together or to any surface by the forces of molecular attraction. For a small particle the attractive force might be as high as 10,000 gs. (gravities). Now that the particles are dislodged and airborne, the flask is quickly placed at the focus of the optical trap. Two forces simultaneously take over, radiation pressure and photophoresis. (Figure 10.) Since both forces are intimately linked to levitation phenomena they will be described in detail but separately to make it less difficult while showing their distinctions. As mentioned earlier, all electromagnetic radiation carries with it not only energy but momentum. It may transfer both in the process of interaction with matter. The force is dependent on the wavelength, intensity (number of volume unit photons) and the particle's reflectivity. The reflectivity of graphite on its cleaved surfaces is high. Therefore playing an important roll in levitation. All matter receives the same amount of pressure from any given photon, but the greater the reflectivity
the more force the particle encounters in an elastic collision as the pressure is multiplied as the photon jumps off (is reflected). Since the weight of the graphite particle is extremely small, approximately 1 millionth of a gram, the strength of radiation pressure at a 1 thousandth of a gram creates a three orders of magnitude stronger force on the particle's local field of gravity, thereby levitating it. As the light pressure enters the flask it slams into the particle, forcing it in the direction of its propagation. Because most of the particles lack symmetry they begin to slowly spin, feeling stronger pressure on the larger surface area axis. As their spin rate increases rapidly the particles begin to increase in mass through *inertia*. A vast slowly spinning cloud begins to form, collapsing incrementally under its own newly generated gravity. As the cloud collapses more towards it center it spins faster (just as a figure skater does when she pulls in her arms). The resulting centrifugal force inhibits the flow of material toward the spin axis (up and down), but not the flow parallel to the axis (outward). The cloud flattens into a disk with a dense lump at its center. Some become like planitesimals, deflected out of the system. Others become like comets in eccentric orbit. Some violently shatter into millions of little pieces caught up in the mass, unable to withstand the force of their own velocity. Eventually it settles into a stable system that are all revolving in the same direction. The stability of the system is equalized by a percentage of light from the back wall of the flask being reflected (re-radiated) back. The radius of curvature of the flask equals the divergence of the light, thereby refocusing about 4% of the pressure back to the center as a restoring force.

*Photophoresis* as an equally strong phenomenon plays a critical role in levitation as well. As each photon strikes a graphite particle it generates an *electron phase reversal*, exactly as described earlier in the interaction with a mirror, but in this instance the reversal in *incoherent* as opposed to coherent. Because a mirror's surface is symmetrical, the reversal remains in phase, but because of the surface anomalies and distortion of the particle by a high rate of speed, the particle reversal is incoherent. This *incoherent electron phase*
reversal is a highly fluctuating electromagnetic field, generated instantly by the liberation of electrons on the surface of the particle by light. This causes the particles to be encased in a sort of electron cloud. When the photon is approximately one half a wave length into the surface of the graphite particle it meets the electron cloud which has been generated by its own presence (as in the mirror). The configuration of the cloud is such that it forces the particle to behave as a spinning motor in an electric field. (The graphite particle is in a sense a mirror and a photo voltaic cell without conductors.) Once an object in a high (frictionless) vacuuum is levitated by radiation pressure and set in motion, by a photon induced electromotive force, it can move (spin) on its axis indefinitely. The intrinsic spin of an individual or group of particles is intimately related to the way in which two or more such particles respond to the proximity of others. As a result of their wave properties the particles will probe each other's presence quite apart from the electric force between them. Because the peaks and troughs of one wave will overlap and interfere with the peaks and troughs of the other. It provides a sophisticated mechanism to communicate information from particle to particle, communicating in unison, one giant microscopic dialogue. This discourse between them will determine the spin rate of the particle. This rate determines the mass of the particle through inertia, and this in turn provides the distance or proximity in which the particles gravitate together. Some of the reflected radiation off the particle has enough synchronicity and direction as to perturb certain particles completely out of the system.

If what I've just defined sounds strangely familiar, it is because these phenomena at play on a larger scale help account for stellar, galactic, and solar system evolution. If we could add more mass to the graphite galaxy (on the order of trillions of magnitudes) the friction would be great enough to create the kind of heat to ignite thermonuclear fusion, the generators at the core of these systems. The graphite galaxies form a score of other results that resemble astronomical events so much its hard to determine which is what in photographs. In a nutshell we have generated the exact same seed (proto-mechanism) from
which everything starts (binary systems, clusters, spiral and barred galaxies, accretion disks, etc.) and we are using poetic gesture as the nucleus in which to influence the evolution of the proto-mechanism (analogous to stellar, D.N.A. Figure 11). During the actual performance Laura provides a determining factor in levitation, the photons re-radiated by her body, her movement, add the new human factor of poetic probability to the galaxy, her presence between the mirrors and flask determine the particular configuration and organization of the graphite crystals, thereby echoing her performance in real time. (Dancing her dance.) This is most certainly not an exhaustive study of these phenomena. Indeed it was not until the mid 1970's that radiation pressure was even considered usable on a terrestrial scale, “Photon Voice” is the first of its kind. But I feel strongly about providing a solid foundation on which to begin to understand the subtlety of the particular forces that are being orchestrated in this type of artistic expression. The “optical image array” is simply geometrical optics comprised of multifocal length Fresnel lenses, sandwiched between 1/8 inch clear plexiglass. The unit has a 180° aluminum swivel attached to a steel tripod for positioning. The tripod is cabled to the ground for stability. The “OIA” create well-defined multiple inverted camera obscura images of Laura's dance in the sky — i.e., when she pours water onto the ground, the image is of pouring into the sky. Also the images Laura sees are upside down as well, her optical landscape provides her the ability to dance in the clouds. The “binocular image inverter” was included in the original design, to accommodate for long distance image transmission, but in the final “DS/DM” short range version it was omitted.

Finally, I have mentioned living art (life) a great deal in respect to “Photon Voice,” sincerely without the intention of becoming monumentally anthropomorphic about the project. But can the questions of life still be reduced to well worn debates in metaphysics? It is worthwhile to question after all what is life? Biologists have raised it, only to side step it and give up. A few 20th century physicists have ventured a definition. It is a basic tenet of physics that things in our universe tend to run downhill, from order to disorder, and at last chaos. The
principle is known to physicists as the Second Law of Thermodynamics. It is known to laymen by the buzzword “entropy.” Life, according to the physicists’ definition, is a huge and intricate molecular contraption that manages for awhile to reverse the trend, the molecules make themselves an island of order in the sea of chaos and even manage to make more of their own kind. A living system is a triumph of order; it keeps itself working far longer than most of its parts would separately. In short, concluded such physicists as Erwin Schrödinger and Eugene Wigner, “In a universe that is running down hill, life is matter that goes against the flow.”¹³ (We are reminded of the tenuous yet poignant life of the graphite crystal galaxy.) However, a living thing consumes a great deal of energy in keeping itself together; it does not actually defeat the inexorable and depressing Second Law of Thermodynamics. Each little victory of self-preservation is achieved at such a great expense of energy that the inanimate world deteriorates slightly faster in consequence of life’s presence, each life in any case must come to an end. But if there is one common factor in the project here and of life as the way we know it, it is that there can be no life of any kind (our life) that exists without carbon. (Graphite particles are simple carbon molecules.) Carbon is the basic building block of life. The versatility of carbon comes from its infinite variety to be put together with other atoms in different ways. Unlike most atoms containing only a few possibilities of connections, carbon is literally incalculable. Most of the original carbon in the universe (the kind we are made of) was synthesized at the center of the stars, two to three stellar evolutions ago — approximately 10 billion years. So it’s more than poetry to realize that indeed stars die as light to give us life; we are ashes of a dead star, and by encoding life (sound, images, motion, presence) existence back into light and levitating, animating graphite particles, are we not in a sense resurrecting the star that dies as light to give us life? Under these criteria life is a condition of distinguishing phenomena especially denoted by growth, evolution, adaptation, etc. and under these definitions strangely enough “Photon Voice” can be assumed to be a candidate, for in “Photon Voice” we have
thwarted if only for a moment the inexorable laws of chaos and created in it and island of order.

“Photon Voice” ultimately as a performance, forged all of these superficially unconnected phenomena and events into a single, simultaneous poetic statement. A giant empathetic expressive organism, heroic line of connection, spanning the cosims. A once in a lifetime making of a mark, living gesture, that lasts only for instant, yet exists forever. Its ubiquitousness became a celebration, communication with ourselves, an echoing of ancient languages, light as our oldest living ancestor, photons, the final spokesmen of human destiny. As the planet revolves the sun sweeps across the face of the earth, striking Laura and our mirrored faces . . . ejected off at breakneck speed towards the destination, careening, they are bridled down, forced into a single poetic point . . . burning into it, our memories. As her photons move, she modulates and caresses the galaxy with the presence, changing the shape, destiny of the little universe, our living imagination. All of this done for the moment, a tiny ripple through space and time. Leonardo da Vinci said on the origin of the first work of art, “it was natural phenomena; a man drawing a line around his shadow in the dust — his place in the sun.” You can view “Photon Voice” in the same way, a little dust, shadow and sun. For three minutes a day it was living art, the process of creating knowing.

After the heraldic drama of “Photon Voice” had gone to sleep, by myself late one evening, it lulled me. A wave of melancholia, flowing over me like a knowing blanket, the ultimate irony, starring off into the infinite desert night sky; penetrating, clear, celestial vault. I saw them ... millions of them, looking at me... the photons. They had travelled their whole lives to come to me and me alone, only to fall and die on deaf eyes. (Figure 12.)
AQUA ECHO

aqua / akˈwa, ākwa / n., pl. aquas [L. aqua, water]: 1. water: chiefly in old world chemistry, pharmacy: liquid of life. 2. a solution, containing or dissolved, esp. in water. 3. Of or pertaining to an indefinite, infinitely large amount of water, ref. all water.*

echo / ekou / n., pl. echoes [L. fr. Gk. sound]: -n. 1.a. repetition of sound, produced by the 3-dimensional reflection of soundwaves from an obstructing surface. 2. sound heard again near its source, after reflection. 3. any repetition or close imitation as of the ideas or opinions of another. 4. one who mirrors behavior, imitates. 5. sympathetic response, ghost waves.*

Very little time elapsed between the execution of “Photon Voice” and the conception of “Aqua Echo.” “Aqua Echo” was developed and executed at C.A.V.S. M.I.T. in March of 1987 as a thesis project. Based on the extended vision of technology as a physical and conceptual tool of artistic expression, it
initiated the reach into dimensions (macro-micro) considered out of scale with experience and skills of traditional art. Certainly a percentage of “Aqua Echo” was wrought out of necessity concerning thesis project deadlines and degree applications, etc. but besides the academic pressure the real impetus for the project was spawned from an emotional reaction to “Photon Voice;” it was explicitly possible to express ourselves in other dimensions. The bulletproof design of “Photon Voice” stemming from many levels (theory; technology; poetry; artistic legibility, etc.) ultimately states calculation, prediction, theoretical and experimental data coincides with and precisely punctuates our poetic intuition; humans have a monumental influence in the universe. Our elated success of “Photon Voice” brought on in “Aqua Echo,” a logical, yet mirror opposite response; the ability to articulately express ourselves, microcosm to macrocosm. (Reverse Direction) If “Photon Voice” embraced grand astro-macrological events, feeding and focusing them through our presence, generating a single common (microscopic) poetic entity. “Aqua Echo” became the desire to orchestrate occurrences on the microcosmic (atomic) scale, through empathetic human apertures, manifesting (our imagination) in macroscopic phenomena. If the emphasis of expression in “Photon Voice” was on a soul searching response to the outward universe, “Aqua Echo” would then be its companion, concentrating ultimately on the discrete (inward) amniotic universe: water. Thus finally expanding the poetic and technological ability to express ourselves in both dimensions. (“Photon Voice”>,<“Aqua Voice”) (Figure 13.)

The history of “Photon Voice” provides a solid realization of the importance and scope of work that can be accomplished in the kind of thorough collaboration Laura and I have; diverse and distinctly separate visions combined to create new extensions and languages. A difficult catechism we had passed in “Photon Voice,” we unanimously decided to continue our work together for “Aqua Echo.”

From the beginning of this joint project we were consumed by an obsession with water (drawn by a sort of trusted intuitive geomancy) images of
deep, humid weightlessness, dark quiet embodiment, oort cloud (our solar system is at the center of an envelop of water comets called the oort clouds; it is 50,000 A.U.'s from earth and has approximately the same spacing of an electron cloud around a nucleus).\textsuperscript{14} This vision could be possibly attributed as a counter acting agent, from the arid, blinding heat of the desert, yet "Aqua Echo" was not based on the miles of intricate and subtle (but real) differences in theoretical models, and their interpretation, as was "Photon Voice," but instead on a simple experimental fact — ice crystals (snowflakes, ice cubes, etc.) in nature are precise recordings, or histories of all events in their lifetime. (Figure 14.) Normal water does not freeze at zero degrees Celsius by itself. It needs a nucleating agent to initiate the process. Ultrapure supercooled (below 0\degree C) water in a controlled environment will remain in equilibrium and will not nucleate freezing until \(-40\degree C\) without extraneous influence (such as human presence). Influence which instantly initiates (nucleates) freezing of an intimate atomic recording in direct response to its new environment, heterogeneous nucleation.

The investigation of ice as a substance has fascinated the sciences and imagination of man probably since the beginning of time. The origin of this investigation of snow and ice crystals is marked by a number of references in Chinese literature as early as the Second Century B.C. "Six generated from the earth is the perfected number of water, so as snow is condensed into crystal flowers, these are always six pointed"\textsuperscript{15} (writings from the Chinese Philosopher, Chu Hsi, 135 B.C.) Apart from the few ancient, historical notes, the first truly landmark discoveries concerning snow and ice are not so surprisingly introduced by Johannes Kepler. Kepler's remarkable essay, "The Sixcornered Snowflake" (1611) began the first scientific investigations of snowflakes in Europe. He was the first to classify the relationship between hexagonal form and the packing of uniform particles in two dimensions as six fold symmetry.\textsuperscript{16} Imagination and insight clearly beyond just admiration of classical elegance and beauty. René Descartes re-emphasizes this symmetry in his publication of "Meteorologia" of 1635, but apparently believed it was initiated by uniform
packing of irregular solids, curiously inverted from Kepler's observations which run concurrent with modern findings. The first published sketches of snowflakes made with the aid of a microscope, which verified the six-sided symmetry and parallel sub-branches were reproduced in Robert Hookes "Micrographia" (1665), still though, very little was understood on the nature and mechanisms determining the growth factor of ice crystals for almost 300 years. Kepler's contribution remained unique until the development of photomicrography, which led to a renewal of interest on the subject in Europe. The first comprehensive change of its kind appeared in 1894 as a paper by Gustav Hellman, the Director of the Institute of Meteorology in Berlin, of particular interest is his system of classification for snow crystals still in use today. Oddly enough from all these years of observations in temperate climates (Western societies), we have only seven words to classify its myriad forms: ice, snow, sleet, hail, frost, hoar frost, and rime. The Eskimo, however, has a much more animated imagination on the subject and includes over 50 words to describe snow alone. (Figure 14.1) It should be considered paramount in our investigation of ice and snow to start of course at the beginning with its main constituent: water. An individual water molecule as vapor in the air, is comprised of four arms (actually electron clouds) extended from the oxygen atom nucleus. Two arms of the hydrogen nucleus are positively charged (protons), and the other two containing no protons, they can be considered negatively charged. The oxygen nucleus contains a total of 8 electrons, two of which are held at the nucleus, while another pair join with 2 electrons from the atoms binding them together. When unisolated molecules pack together as in a liquid, these negatively charged arms serve to attach one another together (molecules). Each negative arm attracts a hydrogen nucleus in neighboring water molecules, creating the strong hydrogen bond. In the liquid state, normal thermal-motion breaks these bonds continuously. However when water is cooled to the freezing point, thermal motion is so reduced it begins to form large, stable clusters: the crystals of ice. Many years ago x-ray diffraction techniques showed that the internal arrangement of water molecules in ice is
arrayed in symmetrical hexagonal patterns, which of course accounts for the macroscopic six-sided form of the snow flake. Yet more importantly, it reveals a good deal of empty space between the molecules. This is one of the most unusual properties of ice, because in most other substances the solid state is more dense than the liquid state. This result is graphically clear when we see that ice floats on water. In “Aqua Echo” we are concerned with the phenomenological mechanisms that trigger this process, changing water from one phase to the next and the human effect on these states, reflections of environment in its atomic architecture.

There are three basic mechanisms that account for initiating nucleation (freezing) in water below 0° C, two of which occur in a logarithmic scale below 0° C and -40° C. Heterogeneous nucleation and splintering, the third becoming effective at temperatures only below -40°C: Homogeneous nucleation. One can imagine the homogeneous freezing of an ultrapure water sample to be initiated approximately as follows: “Waters” structure can be described as “broken down” ice structure, a long range order that is lost, but a short range order conserved, a state in which relatively few hydrogen bonds are broken, but many are bent. As the temperature is lowered, molecular arrangement in supercooled liquid becomes progressively more ice (crystal) like. In the absence of any foreign matter, nucleation of the ice is initiated by small groups of water molecules undergoing random fluctuations in position and velocity, and by chance (probability), becoming locked into an ice-like configuration. This homogeneous particle (ice-like configuration) may cause water molecules to become locked onto its crystal like “lattice” under the influence of its surface force field. Such molecular aggregates will continually form and disappear instantaneously by an introduction of an element of cooperativeness into the hydrogen bonding process, where by bonds are not made and broken separately, but several at a time thus producing short lived clusters of highly bonded regions. These aggregates come and go as a result of microscopic thermal fluctuations, and the probability of an aggregate reaching a given size
increases dramatically as the temperature decreases (gets colder), until it eventually surpasses a critical size beyond which it can survive as a semi-liquid, and so it continues to grow with a decrease of free energy into a nucleus on which to spontaneously nucleate the ice phase.

Heterogeneous nucleation and splintering hold the greatest dramatic aspects for “Aqua Echo” in a tangible sense. The nature and origin of effective nuclei necessary to initiate formation of ice crystals at temperatures warmer than −10°C has a long history of study. The first realistic breakthrough is well known. In 1946 Vincent Schaffer, working at General Electric Research Laboratory, discovered that ice crystals could be nucleated in a supercooled cloud of water by seeding it with dry ice. (Figure 15.) He concluded accurately that dry ice seeds at 78.5 degrees below zero C cause water droplets to freeze spontaneously. Within months silver iodine was being used as ice nucleating or seeding agents in celebrated rain making experiments conducted around the world. 17 For us to understand this process, artificial and organic nucleation, is critical in “Aqua Echo” if we are to have a hand in the poetic license of the phenomena.

Firstly, we must recognize that, in natural atmosphere, an ice nucleus may be activated in at least three different ways. It may form an ice crystal by the direct deposition of water vapor into ice (i.e. acts as a sublimation nucleus); it may act first as a condensation nucleus (perhaps at humidities below water saturation if it has a soluble coat), and then cause the droplet to freeze; or it may be captured by a supercooled droplet and cause this to freeze.

The mechanism of heterogeneous nucleation is not substantially different from homogeneous nucleation, yet it is precisely these minute differences that account for the variety of forms and temperatures in which ice freezes. Unlike the homogeneous chance, organization of supercooled water into ice like configurations, suitable (heterogeneous) foreign particles bond the water molecules to its surface. This new aggregate, having only one surface exposed, creates a shield against vulnerability of thermal bombardment (heat transfer)
which therefore gives it an advantage of a higher probability to attaining critical size at faster and warmer temperatures from which it may nucleate the ice phase.

Splintering or as it sometimes called, fragmentation, share the exact same originating crystals as in homogeneous or heterogeneous nucleation. Preactivated ice crystals through atmospheric evolutionary phenomena oftentimes shatter into thousands of tiny pieces. (Figure 16.) Analogous to a shattered holographic recording, these splinters contain not just information about part of the hologram but instead a small piece containing the whole. Ice splinters produce a concentration of $10^2 - 10^3$ times higher amounts of nuclei in the atmosphere than do all other sources, playing a role that if not primary, then in the very least instrumental in the formation of nuclei in nature. The main difference in splinters and heterogeneous nuclei is that the freezing threshold of effective artificial nuclei have a certain amount of *lagtime* associated with their efficiency, a logarithmic scale that determines the exact temperature, and time at that temperature, required to freeze water. The effectiveness of each nuclei are determined by their atomic structure and can vary up to $40^\circ$ C. in temperature. Splinters on the other hand freeze supercooled ($0^\circ$ C.) water instantly upon contact, because they are exact recordings of the crystals. Recordings in ice (water), not foreign nuclei, each splinter facilitates an instant freeze, because their atomic lattices line up correctly, allowing a spontaneous creation of thousands of full-sized clones from only a single splinter (analogous to DNA).

Ice splinters are produced in certain circumstances when supercooled water drops freeze, usually produced by a steep fall in a vertical temperature gradient of cold air, the nucleation of droplets followed by the formation of dendritic ice crystals spreading rapidly through the drop and around its surface; the drop temperature momentarily raises to $0^\circ$ C by the release of latent heat, *fusion*. Freezing proceeds radially inward, controlled by the dissipation of latent heat to its environment. Expansion in the second stage of freezing releases air bubbles trapped inside the structure, producing a thin transparent shell that is quite mechanically strong. However, this solidifying center creates great
pressure, rupturing the shell at its weakest point, first as bulges, then frequently as spikes. If the expansion of the core cannot be accommodated, large cracks and fissures develop, causing the drop to explode violently, shattering into many fragments 50 to 500 microns in diameter creating \textit{nuclei storms}.

We have described in certain detail the mechanisms that trigger the change of phase of water (liquid) to (solid) ice as a combination of temperature and nuclei, yet the investigation of the nuclei should not elude discussion. They in part extend the poetic limits of “Aqua Echo,” to intimate human contact. Since a cubic meter of atmospheric air contains only ten active nuclei at $-10^\circ$ C., the nature and origin have very special interests. Evidence of nucleatic origin points to three main sources: mineral dusts, organic material and soil, and industrial smoke. There is even new evidence to support extraterrestrial sources: meteorites (carbonaceous chondrites, carbon particles like in “Photon Voice”)!\textsuperscript{18}

Of the thousands of tested terrestrial nuclei found in the atmosphere, only 16 nuclei are found to be effective nuclei between $-10^\circ$ and $-15^\circ$ Celcius, no warmer. They are mainly silicate minerals (clay), substances which are all minor constituents of the earth’s crust. There is a tendency for the more effective inorganic nucleators to be hexagonal crystalline symmetric, symmetry in which the atomic lattice arrangement is reasonably similar to that of ice. There are of course exceptions; nevertheless for all inorganic substances that are active above 15 degrees below zero C., it is possible to find a crystal face on which the atomic spacing differs from those of ice by only a few percent. Many nuclei are calculated by “epitaxy” or crystal lattice misfit; the maximum misfit usually for effective nuclei is a ratio of 3:1. A perfect example is silver iodine whose nucleating temperature is $-15^\circ$ C. and calculated lattice misfit is .06 (4.58) angstroms different than ice (4.52). (Figure 15.) This is a nucleus it of course has been taken advantage of and it has been used with dramatic results in rain making and atmospheric tests. It is significant that common materials such as sea sand are not active, since the quartz of ordinary sand has a fine hexagonal crystal structure resembling that of ice. One could easily assume it would be an
excellent nuclei, but superficial resemblances in structure are not enough. Kaolinite (a clay crystal that strangely enough resembles the make-up of human flesh), which initiates ice formation at nine degrees below zero C. is of great abundance, common enough to provide a very important source of nuclei, but at the atmospheric altitudes where rain (ice) is initiated there are no high concentrations of these particles.

By switching arenas of nucleating properties from inorganic to organic compounds, a remarkable change occurs. In the late fifties two Soviet scientists, Bashkirov and Krasikov, found a number of organic compounds that were extremely effective between $-7^\circ C$ to $-2.5^\circ C$ — an increase in average effective nucleating temperature by $10^\circ C$. (Figure 17.) In respect to ice formation this is a monstrous leap in temperature. Yet surprisingly very little interest was aroused. It wasn't until the mid-1960's that amino acids, protein crystals, and human hormones (testosterone, progesterone!) were tested and found to be astronomically more effective than any other substances yet experimented with, nucleating at temperatures as high as $-1.5^\circ C$ to $-0.04^\circ C$. (31°F.) The staggering implication is simple. We provide the most active nucleatic material known (ice in our own image)! In general the high nucleating ability of organic compounds suggests a more complicated picture. By the existence of polymorphic forms which lack the information of the crystalline structured counterparts, the balance of evidence seems to tilt towards molecular bonding sites — sites where specific clusters of bonding groups fit the oxygen atoms in a pattern of close packed ice planes. Steps, cracks, and cavities on the surface are often preferred sites of nucleation, probably because of the tendency for absorbed molecules to become trapped (locked into configuration) there.

This possibility of certain nuclei being more effective than others, suggests the investigation of nuclei that have been involved in ice formation more than once. In the course of experimentation over the past 20 years, surprising discoveries have been made. Dozens of the terrestrial dusts and organic compounds become progressively more efficacious if they have previously
nucleated ice crystal formation. They become preactivated or trained, thus a nuclei like kaolinite, nucleating ice initially at a temperature of $-9^\circ$ C., leaves behind nuclei whose new effective temperature is $-4^\circ$ C., or five degrees higher! As the ice of rain evaporates in a dry atmosphere, the bulk of ice surrounding the nucleus is removed during the drying process. However, microscopic germs (embryos) of ice retained in pores and crevices survive, serving as more effective nuclei when the particle is again introduced to a supercooled body of water. If some particle with initial poor performance can be taught to leave behind trained nuclei capable of freezing only a few degrees below $0^\circ$ C., it is not unreasonable at all then to assume a single nuclei under the proper conditions can increase its original (clone) population millions of fold, while each successive generation becomes more and more efficient (evolves, adapts, reproduces, etc.)!

Before the final stage of “Aqua Echo” is set, we must scrutinize a final potential, the one aspect that is most visually captivating — and carries a certain enigmatic charm for all of us since we were children. (Figures 18, 18.1, 18.2.) The delicate complexity, beautiful symmetry, infinite variety of growth, and patterns, snow crystals. Growth is the tangible, yet complex process of recording during a phase change, the locking down of every moment’s subtleties into another language, a new reality Once the aspect of nucleation occurs another sophisticated set of mechanisms take over, determining the growth and outward appearance of the crystals. When the solidification, growth process, proceeds from outside to inside, as in an ice cube, the boundaries between solid and liquid remain stable and smooth at a speed controlled by the ability of the walls to draw heat away. But when crystals solidify outward from an initial seed — as a snowflake does, grabbing water molecules from moist air, the process is extremely unstable. Any bit of boundary that gets out ahead of its neighbor gains a distinct advantage in picking up water molecules, therefore growing faster at the tips and dendrites, “lighting rods,” giving birth to subbranches. (Figure 19.) We have know this much for years, but the physics of heat diffusion and unstable
growth cannot explain completely what we see when we look at a snowflake. Another process is intimately at play.

Whereas heat diffusion creates instability, a costly expenditure of energy to maintain rough surfaces, surface tension, on the other hand, creates another process, stability. Nature preferring smooth boundaries like that of soap bubbles, because they are more efficient yet cost less energy. Diffusion is indeed a large scale macroscopic phenomena involved in atmospheric transfer of heat. But surface tension is at its strongest position as a guiding force on the microscopic scales. This delicate balancing act of stability/instability amplifies the microscopic preference, generating the magnificent effects characteristic of dendritic snowflakes, mirroring their environment. This sensitive relationship to the molecular crystal structure of a solidifying substance punctuates the case in point, the six-sided preference. These layers and branching tips at any moment depend on incrementally sensitive changes in temperature, atmospheric pressure, particulate matter, and humidity. Snow crystals are indeed infinitely detailed, accurate recordings of every event in their lifetimes.

Although snow crystals in nature occur in an almost incalculable variety, giving a certain validity to the story that no two are ever the same, they can all be classified into three basic forms: hexagonal prismatic columns, thin hexagonal plates, and the branching hexagonal stars or dendrites. The specific classifications, however, are largely controlled by the temperature of the air the crystal grows in and their size by supersaturation. It is observed that snow crystals grow as layer upon layer of new material sweeps across its surface; the layers travel at speeds that approximately are variable inversely proportional to their thickness. Consistent with the idea that they proceed by molecules landing on the crystal surface from vapor. The surface tension migrates water across it onto the growing (leading) edges. The rate at which water molecules migrate is temperature dependent, and in a rather remarkable manner suggest certain temperatures 0°C to -3°C and -8°C to 25°C that there is a net surface migration from the basal plane to the prism faces, biasing the growth of flat
dendritic plate crystals and at temperatures between -3°C and -8°C and also between -25°C and -40°C. The habit is reversed, and the net flux of material from the prism faces to the basal planes increased, preferentially growing prismatic columns of needles. (Figure 20.) These cycles of shape changes are always reproducible, and the boundaries are very sharp. For example, the transitions between plates and needles at three degrees below zero, and those between hollow prisms and plates at eight degrees below zero, occur within temperature intervals of less than one degree, and these observations at normal temperatures and humidities never vary.

The effects of supersaturation (moisture) in the atmosphere on growth rate simply alter the speed or rate at which the crystals grow. The greater the supersaturation, the faster the growth. Once the basic shape of the crystal has been determined by nucleation, the vapor field around the crystal orients itself to the inherent atomic geometry and tends to maintain it. The lines of surface tension create a higher saturation that concentrates towards the edges and corners of hexagonal plates accentuating its development. This moderate supersaturation suggests the excess material is diffused evenly across its surface. However at higher supersaturations the surface tension is unable to cope with non-uniform deposition of material, thereby increasing its surface area by complexed dendritic side branches, the familiar rhythmic growth of star shaped crystals.

The entire spectrum of micro-events, phenomena for crystal generation from atomic architecture, phase change and symmetry, become built into the genuine event, they are more than the basis for “Aqua Echo,” they become “Aqua Echo,” they (we) are the explicit and poetic creation, development and reproduction, of genetically engineered (designer) ice nuclei and their recording environments, art apparatuses that initiate the mass fabrication of atomic recordings, trained nuclei, capable of teaching in minute detail our nucleating response (poetic expression) to every supercooled water molecule in nature, (billions) they come in contact with. The success of “Aqua Echo” is in part
generated by a delicate adaptation of these sophisticated naturally occurring systems, into a vehicle that yields more than abtruse ramifications, but unfolds this dynamic process. Because of the inherent temporal qualities of both ice crystal formation, and performance, their simultaneous evolution truly reflect (echo) one another. The critical distinction of this type of work lies in the bond established between the art apparatus and performance, the intimate connections of two communication systems.

The art apparatus for "Aqua Echo" are quite easily divided into two categories. **Recording apparatus** and **sublimation systems**. The recording apparatus consists of the **ice nucleating device**: an array of supercooling and nucleating systems for generation of initial nuclei and event recordings, also high powered stereo microscopy gear for detailed observation. **Aurora ice crystals**: large bodies of ultra pure supercooled water, a vessel, in which to seed mass creation of performance clones, creating brilliant colors when viewed in polarized light, and **laser light place**: Helium-neon laser scanning devise, used as an optical metronome, for plotting, velocity and position of dancers during nucleating process. The sublimation systems are comprised of a **ripple tank**: a large optical water lends which focuses light wave patterns on the effective surface area (floor and walls) of the performance space, and a double convexed **water lens**: floor lens creating magnified images of dancer feet: each sublimation system contains the previously cloned aurora ice crystals in liquid state (water) sublimating as vapor into the atmosphere.

The development of **the ice nucleating devise** required a substantial amount of experimentation and innovation to achieve the anticipated results. There are almost no support materials of any kind that do no interfere or react adversely with ice, changing its systematic process of crystal formation. The fine crystallization patterns of ice are extremely sensitive to substances in which they are on or are in contact with, even the electrical characteristics must be taken into consideration. To find a surface on which facilitates unhindered freezing suggests a non-metallic high surface tension environment — a perfect example
as mentioned earlier, a soap bubble. (Figure 21.) The structure of liquid detergent allows water to spread readily into thin films, perfect for nucleation, and since the molecules of the detergent are in continuous random motion, they do not provide any rigid lattice pattern that might easily influence the growth of the ice crystals. The detergents surface offers little frictional resistance to moving particles, so the forces of crystallization act uninhibited, allowing the water molecules to move into the most natural solid configuration. The nucleating system from the inside out consists of a 2 1/2 inch diameter round nylon coated chrome ring. Used to stretch soap film on, and act as substrate for ultra pure water as the nucleating surface. This ring is locked on a tiny lip of a 2 1/2 inch diameter lathed brass pipe 6 inches long, with a 1/16 of an inch wall diameter, on each end of the brass tube are mounted 1/8 inch thick round plates of optical glass, 2 7/16 inches in diameter, the windows permit direct and oblique transmission of illumination for examining the crystal growth. These plates are mounted onto the tube via two lathed aluminum mounting brackets, 3 inches in diameter, with inset grooves to match the tube and optical glass. These mounting brackets have small set screws to attach to the ends of the tube. This complete mechanism is coated with glycol to reduce condensation, and then set inside a 3 1/2 inch high by 5 inch diameter clear plexiglas tube. The entire assembly is bolted to a 5 inch diameter piece of 1/4 inch clear plexiglas at the bottom. The 1 1/4 inch circular trough is packed with crushed dry ice (-78.5° C) and Acetone (good thermal contact). The interior is now completely sealed off except for three small holes place equilaterally around the aluminum bracket. These holes become tiny pressurized jet streams of atmospheric air being pumped in, because of the extreme differences in temperature, flushing microscopic nuclei (generated during the performance) across the surface of the membrane. The length of the tube oddly enough plays a crucial roll, providing the extraordinarily narrow temperature gradient for nucleating between -3.5° C. and -1.5° C. Temperature provides an exceptionally effective filter, "screening" out any possibility of nucleating anything but human performance produced
organic nuclei. Since each nuclei has roughly a single temperature in which they can initiate the phase change, the threshold window for nucleating is precisely tuned to a matching human response.

The membrane mixture is a solution combined of one part liquid detergent (clear), one part glycerine and one part ultrapure water. The ring is dipped, then locked into place inside the brass tube seconds before the performance begins. The entire nucleating devise is mounted on an adjustable cantilevered arm, extending from a large boom tripod. The ice crystals are obliquely illuminated from a small penlight placed at 45° to their surface, highlighting their stepped surface structure, a wide throw 3 volt lamp is placed below for transmission lighting, producing high contrast for the internal crystal structure. A wide field stereo zoom microscope is attached to the same arm, 12 inches above the crystal surface, used for detail observations. (Figure 22.)

The temperature gradient is set for a freeze/thaw ratio of 3:1, freezing, melting and refreezing three times in a single 15 minutes performance, each time the nuclei initiate the process they become more and more efficient, creating ice crystals within 1/10 of a degree below zero, and increase of effectiveness 3° in temperature. During this period of the performance, the crystalline structure is making quantitative measurements of the temperature, atmospheric pressure, and particulate matter in direct response to the performers, audience and environment, all of these signals provide a contribution to the freeze matrix, a guidance system of almost incomprehensible magnitude. The outward appearance of the ice crystals usually follows a sequence of events in which the thin film of the water begins to freeze at one or more points (nucleating sites), the crystallized area growing radially, in circular or hexagonal grain boundaries until the entire surface is frozen. While growth occurs, ice exposed to atmosphere sublimes as occasional molecules acquire enough thermal energy to break way from the crystal lattice and escape as vapor. The amount of energy required for escape depends on the temperature to the atmosphere, the geometry of the crystal, the structure of the grain
boundaries and the presence of “outside” the threshold impurities. In effect the conditions of the performance actually etch the ice surface, selectively creating patterns of polycrystalline structure to stand out in dramatic relief. (Figure 23.) This engineered substrate is saved for igniting the chain reaction of cloning in the aurora ice crystal.

The aurora ice crystal is a wedge shaped plexiglas vessel, 24 inches by 24 inches square. Its edges are milled plexiglas, tapered from 1 inch at its bottom to 1/32 of an inch at its top, thus to facilitate nucleation from a single edge. It contains two small stainless steel set screws to allow the filling of ultrapure water, keeping the external contamination to a minimum. The entire detachable assembly is mounted on a square aluminum C tubular frame which is fastened to a large dolly tripod. The roughly one gallon of pure water per crystal is obtained from a triple distillation, millipore filter process. Before each performance, the previously nucleated ice crystals (recordings) from the installation are introduced into the large supercooled body of ultrapure water, held at equilibrium in a freezer at -10° F. This temperature is maintained so as to be on the low freezing threshold of our microscopic trained nuclei. The moment they are released into the supercooled H₂O, they begin (cloning) teaching our specific nucleating gesture to the memory erased aurora ice crystal. In seconds it is a solid (macroscopic) crystal comprised of atomolecular recordings of our presence, through thousands of generations instantaneously, it has begun to mutate, evolve and adapt. Reproducing its efficient system into a final manifestation, a complete personna of our work in another medium, with a presence of its own. On such a large scale the millions of different crystals are almost impossible to see in ordinary white light. But because of ice properties that leave it slightly birefringent it is imperative that we polarize the light to reveal its complex internal structure. In doing so the light supplied by a 300 Watt projector is transmitted through the crystal organized in a single plane of vibration (linearly polarized). This plane of vibration is slowly rotated along the optical axis. Light whose axis
has been rotated 45° in respect to the parallel or perpendicular lines of the polarizer and analyzer, is the only light transmitted, and is dependent on wavelength. (Figure 24.) Because each wavelength of light travels slightly different speeds through the crystal, the thickness and orientation of the crystals selectively filter out certain wavelengths being transmitted thereby creating the brilliant colors. The colors can then be used to calculate the inherent structure of the ice crystals. This phenomenon can be increased to its maximum potential if the aurora ice crystal is positioned horizontally at 45° during freezing. This creates a preferential position of the ice crystal lattices for viewing in polarized light: the breathtaking colors of the crystals supply a constantly changing array of 3-dimensional color patterns (similar to a hologram). An eerie documentation in our own image, striking a strange sense of awe and knowing in the beauty of the mechanisms at play.

After all of the technical and emotion effort to create these crystallized performance memories, it somehow superficially seems inappropriate to just let them melt away. Yet this freedom is bound by a certain poetic justice. We have tagged our work of art, our thoughts and our feelings to a magnificent almost unstoppable poetic monster, that we have taught to adapt, teach and survive in its own natural system. The sublimation systems serve just this purpose, to allow the evaporation of our creation into the atmosphere and the air we breathe.

The ripple tank is a large 6 x 4 foot aluminum framed, 1/2 inch thick plexiglas sheet. It is bolted to the floor and ceiling and hovers like a transparent cloud over the performance space. Suspended by cables, approximately nine feet, three inches above the ground, its leveling adjustments are made by eight turnbuckles connected at the cable mounts. Its smooth glass surface is filled 1/2 inch deep with a thin sheet of water, the melted recordings from the aurora ice crystals. Mounted just near the ceilings at 18 feet above the floor is a 500 Watt quartz monofilament bulb with barn doors. As the source is aimed directly towards the floor the light floods through the thin water lens and is stopped down to the effective aperture of the ripple tank, covering about 80% of the
performance space. During the performance the water interprets any subtle or dramatic movement in the space into vibrations, releasing moisture and creating ripples which alter the surface of the water causing it to behave like a fluctuating lens, focusing undulating wave patterns of light across the floor up the walls, and washing into the laps of the audience. These webs of light, ebbing and flowing like radiant tides, provide a fitting end for the phenomenological crystal process, and the opportunity for the first gesture of our experiencial journey. (Figure 25.) A hand stretched out across the surface of the water, a single point erupts in concentric circles, spreading outward and outward, in an endless beginning.

The water lens is an 8 foot long double convex lens, filled also with the melted aurora ice crystals. It is bolted to the floor on a 3/4 inch plywood foundation, and its seams are bound by 1 1/2 cold rolled angle iron, matching the curvature of the lens. The interior floor surface of the lens is laminated with mirrorized plexiglas, and has an exterior light source. The optical images of the lens magnify not only the movement in the space, but our ideas and influences there as well.

The laser light plane is a 12 milliwatt helium-neon laser scanning device that sweeps out in metronomic time (3500 rpm) a 360° flat plane of intense red laser light. Because of the stroboscopic effects of scanning it captures in real time, the velocity position and momentum of movement from the dancers as they wade in a veritable tide of light pinpointing gesture to specific nucleating processes.

In conclusion, the casualness and comfort in which we throw around atomic and molecular events as though they were beach balls may quite plausibly allow the true macroscopic implications of "Aqua Echo" to be eclipsed. Ultimately we have generated millions of trained nuclei, nuclei more volatile and efficient that those normally produced by atmospheric conditions in nature. Their specialized ability places them as a species of poetic ambassadors, carrying and multiplying our message, undyingly ... forever, a disarmingly gentle cloud nurturing the precipitation of celebration. It is from this particular perspective I
consider our intentions a new precedent in the least, if not certainly a more benign communication, quite different from what we have traditionally released to rain down on peoples heads from the sky. (Figure 26.)
The rapid fire succession of "Photon Voice" and "Aqua Echo" built up a great deal of inertia, a kind of critical mass of skills and confidence in the direction our ideas and theories were projecting us. Exactly 10 days after the completion of "Aqua Echo," Laura Knott and I received a telexfax from Kassel, West Germany. The message was an invitation to the internationally acclaimed
exhibit of art, *documenta 8.* (Figure 27.) Documenta is held only twice a decade and is sponsored in part by the West German government and an array of other national and international organizations and corporations. Documenta’s heritage as an exhibition of unprecedented magnitude, amplifies its commitment to literally documenting the world of art in its time. It seemed only natural that the invitation and opportunity provided us with the possibility to create a performance / installation that considered not only spanning the dimensions of the discrete cosms, but to bridge the great physical and cultural distance between our two countries. However, the significance of punctuating our differences, which in most respects are fewer than many, was overshadowed by an image that struck me as a far greater breach of space and time. In their respective units of measurement, kilometers/meters, the magnitudinal distance between the sun and the earth, is the same distance as a human to a photon! I was stymied by this vision of an awesome abyss opening before me, a “Sky Chasm” of unimaginable proportions. It is as if I felt a sudden sense of vertigo, space between something we all live every day of our existence with. If anything needed to be bridge it was this. If “Photon Voice” reached through a human aperture from macrocosm to microcosm and “Aqua Echo” spawned from a single microscopic nucleus, a poetic event to macroscopic scales, then “Sky Chasm” should extend and focus our vision in both directions, macrocosm to microcosm and microcosm to macrocosm. I was still emotionally attached to the strong feelings developed from “Photon Voice,” that I had invented nothing and discovered nothing, it was the nature of light. If I could encode our sounds, our images, and presence in to it, it was already there, I was just overlooking what always had lived there. I began working on ways in which to listen to images, to use light to measure itself. Not just ways to encode what I wanted in the light, but to see, hear, and feel the way it interpreted and understood our presence. I developed audible holography as a vehicle for this type of exploration.

The instrumentarium for “Sky Chasm” are based on a hybrid Michelson interferometer and current state of the art holography. The interferometer was
invented in 1880 by physicists A.A. Michelson as an extremely powerful and
accurate optical instrument using the precise measurement of a wave length of
light as a that frame of reference for calculating the earth’s drift in the
luminiferous ether. The luminiferous ether was the all pervading substance
which lay at the basic foundation of the paradigm James Clerk Maxwell had built.
His accomplishments, in the Nineteenth Century view, had been to unify the
ethers of light, radiant heat, electricity and magnetism, and although the ether’s
properties of tenousness (invisibility) and rigidity (immobility) seemed
paradoxical in comparison with the properties of ordinary matter, the ether
nonetheless was able to provide a consistent basis for electromagnetism. If
radiation is a wave, it needs something to (wave) propagate in. A single
wavelength of light is roughly 500 millionths of a meter, and it was assumed that
the high velocity (18 miles a second) motion, of the earth through the galaxy
would create an ether wind, a breeze which would cause a slight change in the
time travel of two perpendicular beams of light, split from a single original
coherent source. When the twin beams are allowed to recombine, after
traversing separate optical paths, the resultant intensity shows variations in
amplitude (constructive and destructive interference) fringes, which arise from
variations in relative phase of the light upon recombining (interfering). However,
the predicted displacement of the interference patterns (4 wavelengths) were
never found, and the illustrious history of the interferometer, and constancy of the
speed of light, became the devastating edifice upon which Einstein built his
theory of special relativity.

Despite their similarities, holography is not a direct descendent of
interferometry, its history is generated from the field of electron microscopy and
photography. Holography was invented in 1948 by Dennis Gabor as a possible
solution to increased magnification and resolution of electron microscope /
images. An electron diffraction image would be scaled up from a photographic
plate to its optical ratio equivalent, and illuminated with light in hopes of
magnifying the image 100,000 x, unfortunately the obstacles were too many, and
successful holography had to wait till the introduction of the laser in the 1960’s. In order to point to the fundamental differences between holography interferometry and photography, we should understand in a general way how each works. Photography, as we know, basically provides a method of recording the two-dimensional irradiance distribution, geometrical intensity of an image. Generally speaking, each “scene” consists of a large number of reflecting and radiating points of light. The waves / photons from each of the elementary points all contribute to form a complex wave, which we will call the object wave. This complete wave is transformed by the optical lens in such a way that it collapses into a two dimensional image of the radiating objects. It is of course this image which is recorded on the photographic emulsion.

Holography, on the other hand, is quite different. With holography, one records not the optically formed image of the object, but the object wave itself. This wave is recorded in such a way that it captures the relative phase of the light, something photography destroys (unable to record) and the subsequent illumination of this record serves to reconstruct the original object wave, even in the absence of the original object. A visual observation of this reconstructed wavefront then yields a view of the object or scene that is practical / indiscernible from the original. It is thus the recording of the object wave itself, rather than an image of the object, which constitutes the basic difference between conventional photography and holography.

“Sky Chasm” and “Photon Voice” are in substance based on the exact same theoretical foundations, the constancy of the speed of light and special relativity. Their major differences, however, outside the technical apparatus used to achieve them is, “Photon Voice” is firmly planted in theory, the mathematical frame of reference to confirm our artistic intuition, where as “Sky Chasm” is locked into the actual analysis and experimental practice of measuring the dialation and time travel of individual wavelengths of light.

For both holography and audible interferometry (holography), one starts with a single monochromatic beam of light that has originated from a very small
source. This requirement creates the condition that the light be spatially (geometrically) and temporally (frequency) coherent. The requirement of coherence means that the light should be capable of displaying interference effects that are stable in time. This is currently achieved by TEM\(_{00}\) mode gas lasers. In holograph and audible interferometry. This single beam of laser light is split into two components — one of which is directed toward the object or scene; the other is directed to a suitable recording medium, usually a photographic emulsion. The component beam that is directed to the object is scattered; or diffracted, by that object. This scattered wave constitutes the object wave, which is now allowed to fall on the recording medium. The wave that proceeds directly to the recording medium is termed reference wave.

Inaudible interferometry the two component light beams are also separated then directed at right angles to one another, finally recombined by mirrors to the interferometer's output. In audible interferometry, however, there is no object wave or reference wave, each beam is simultaneously both! The object or scene has been replaced by modulated time, and our recording medium is not a photographic plate but instead a photo detector. Since the waves of both holograph and audible holography are mutually coherent, they will form a stable interference pattern when they meet at their respective recording media. These interference patterns create a complex system of fringes, bright and dark spatial variations of amplitude irradiance that are recorded in detail by photographic emulsion or photodetectors. The interference patterns are unique to their particular waves and different object waves or temporal modulations produce very different interference patterns. The detailed permanent recordings of these patterns is called a hologram (Figure 28), from which the word holography is derived. The record now consists of a complex distribution of information corresponding to the recorded interference patterns. When a spatial hologram is illuminated with light similar to the original wavelength and position used to record the hologram, light will only be transmitted through the recorded interference fringes. This transmitted wave
exactly duplicates the original object wave. By viewing this wave, one sees an exact replica of the original object. The same is absolutely true for audible holography, however, we have sacrificed our waves as photons to liberate electrons. These electrons are mirror images of the photons, they are boosted to create two signals, one to be amplified, and they listen to, the other to be deposited as a fluctuating magnetic field on a cassette audio tape. The hologram is not an acoustical analogy to light, but is the actual electrical signal liberated by the light. Upon reconstruction of the hologram, this fluctuating magnetic field produced by the light creates an electrical signal which is the exact duplicate of the photons in the interference pattern, thus reproducing the sound of the original microscopic wavefronts of light as they collided to create the image. Holography’s triumph over photography is that it can record the relative phase (instant of time) of light off an object to reproduce a three dimensional object wave (image) of the original. However, it falls short of audible holography in that it cannot record even the slightest temporal change. Because of the inherent astringent requirements in spatial holographic recordings, there can be no vibration, not even the slightest, because if a movement of even a quarter of a wavelength of light (100 millionths of meter) occurs during exposure, the microscopic fringes will overlap, bright on dark, dark on bright, and will wash out the image. So therefore a spatial hologram is only a recording of the temporal or spatial coherence of the source (laser), a virtual exposure of only 1/100 trillionth of a tenth of a second (10^{-15}\text{sec.}) of time. Audible holography on the other hand can record and construct in real time any plastic modulation of temporal or spatial coherence. Holograms of dynamic time dialations in the wavefronts of light, as measured by light itself. It is a hologram that records the simultaneous expansion or contraction of time travel. You are listening to the speed of light, the space between light waves, “Sky Chasm” (our image), in real time.

There is a trade off however, in recording audible holography you destroy, not the seeing of the image but the permanent recording of the spatial image. By
the nature of the beast, audible holography is based on the recording of photons, and spatial holography, on the recording of waves, by measuring one we destroy the other (Heisenberg’s Uncertainty Principle). We can’t have our permanent image and hear it too! Spatial holography on the other hand does the same thing, it discards the possibility of any movement, any change. It is only capable of static images (*through multi-plexing, motion can be given to spatial holograms, yet these are all separate recordings of individual events, like a film, not a coherent phase relationship in time).

In its performance/installation environment, “Sky Chasm” is designed to create holographic images of dynamic wavefronts of time, coherent/incoherent phase variations in light. These images of interference patterns are generated by human presence, by the introduction of minute disturbances, vibrations, changes in the local temporal coherence of the system. These complex modulating interference patterns of the images are converted in real time into sound. The detectors decode the time dilations of the microscopic wavefronts of light that are out of phase and the constructive and destructive interference between the two.

The photons, by using photovoltaic cells are converted into electrical energy which is read by a stereo amplifier, constructing sound directly from light. The wave fronts have encoded living performance, into the language of light. In listening to the interferometer, you are listening to the speed of light, a law that governs the universe, creating images, sound, and presence on the edge of the visible microcosm, the scale of 240 millionths of a meter.

The sound of light, strangely enough sound like what you would expect it to, waves. The vibrations from the surrounding environment are converted into differences in the transit time of light. This determines the spatial coherence of the holographic system, the geometrical separation of the source. This separation and configuration of the mirrors, produces the fringe patterns which are read by the detectors. Movement also changes the temporal coherence of the hologram by Doppler shifting the frequency of the light, the speed of light is
constant, but the motion of the source, away or towards the detector, shifts the frequency of sound to a higher or lower pitch, depending on its direction of motion. The excitation frequencies of the detectors are increased by using amorphous and polycrystalline photo detectors wired in as photoresistors to the amplifier. The work rate of converting photons to electrons is spread out to higher frequencies by the amorphous cell and lower frequencies by the polycrystalline cell. By being used as resistors the two cells switch between listening to dark and bright fringes, to create an expanded signal, thereby increasing the audible range of the system. The sound created totally depends on the environment but ranges from an ominous rolling thunder to a high pitched almost synthesized trill. It can even detect and broadcast a heartbeat that is in close proximity, or the slightest vibration like the drop of a pin.

The images that correspond to this production of sound are undulating interference patterns, comprised of approximately ten wavelengths of light. Since the light is from a 12 milliwatt helium-neon laser, the fringes are a contrast of jet black and brilliant red. My hybrid interferometer is based on expanding spherical waves which allow for the extreme magnification of the fringes (24 million power). These waves are responsible for the vortex of concentric circles, ranging between falling inward or projecting outward.

These holographic interference patterns are imaged on a large 2 foot x 4 foot ground glass screen with the small detectors at the center.

We have discussed the optical construction and real time sound production (light to sound) of audible holography. However, there is one final factor that remains to be explored before the actual performance description, reconstruction. The holograms as mentioned are recorded as stored light on a magnetic audio cassette. The conversion (reconstruction) of sound back into actual radiant light would violate the most fundamental principles of physics. Yet it is possible to synthesize a spatial holograph from this recording. However it would require a frameless holographic camera, and endless photographic plate (holographic film) and a frameless holographic projector. These systems, of
course, not only don't exist, but we don't even have the complete technology to
invent them. (*I'm working on it.) Still the “spatial image” produced would be
seen by the eyes as a light source at infinity moving at an extreme velocity in one
dimension! Therefore its modulation would be completely undetectable by our
eyes (just like a star!). We then are back where we started with an audible
hologram needing to be reconstructed back to light. Ultimately I used a battery of
“variable reflector modulating heliostate arrays” which I called, “interference
transmission arrays.” They are more versatile than the original “Photon Voice”
desert version, and also there is a group of five transmitters which through
interference themselves can construct a more powerful optical signal at greater
distances than the same size single surface reflector. The arrays are driven by
the light signature recorded on the magnetic tape, and in a single step is
converted back into sunlight. This light can be of course decoded back into
sound from the light by using an “optical stereo demodulator.”

As a performance “Sky Chasm” was centered outside on the lawn of Aue
Park in front of the “Orangerie,” one of the main museums at documenta. “Sky
Chasm” was separated into a series of four performances, over the next three
days — 10, 11, 12 of July, 1987. The first performance was at night, the second
the next day, another the same evening, and a final performance the next day.
The evening performances were developed for the construction and recording of
the holographic images into sound. The daytime performances orbited around
the five “interference transmission arrays” and their reconstruction of the
previously made holograms back into light. The night time performances were
dark and very intimate, the crowds would huddle around the red glow of the laser
and holographic equipment as if it were the warmth of a fire.

To produce these nocturnal events required the complete set up and take
down of all the complex optical appliances every evening, for holography this is
a contradiction in terms. We must remember in order to hear a single
wavelength of light, we must be able to see it. These requirements are a
hundred times more demanding than spatial holography. If a perfect photon
could orbit the earth in a circle, it would complete 7.2 revolutions in one second. My equipment on the other hand must be so accurate, that it can determine the difference in distances two separate photons have travelled in less than 10 centimeters, 5 billion times shorter than the lights one second journey around the planet. (*It could possibly rank as the smallest visible work of art in the world.) Concurrently, it also must remain stable, precise to within 240 millionths of a meter continuously even during the most violent and abusive actions incurred in the performance, the absolute elastic coherence of all the optical hardware must be maintained during any point of their dialated and return configuration. (Figure 29.) Needless to say a holographic recording of this type is not only a triumph of engineering, but also of the will. The comprehensive nature of holography shows that it records every point completely across the whole hologram. An audible holograph in turn records everything as well, wind, trees, buildings, cars, people, anything that generates even the most minuscule motion. These dialations and contractions of light are broadcast as live sound during the performance through a special optical preamp, then into the re-engineered compact disk inputs on a large acoustic wave technology sound system. Simultaneously the photons are being deposited as an electrical signal on an audio tape for later retrieval. By the end of the performance, instead of applauding, people had sort of caught on that their presence and participation was part of the hologram too. They began jumping up and down, crawling on the ground, something / anything to create their own distinct signature in the light.

In the day time events the previous evening's hologram was reconstructed into sunlight using the battery of "interference transmission arrays." And people returned to hear/see their image released as light to live forever in the sky. Figure 30.

I have barely touched the surface of "Sky Chasm," indeed both "Aqua Echo" and "Sky Chasm" have suffered under the detail in which "Photon Voice" was covered. May it then, I hope, suffice to say that "Sky Chasm" was a
collaboration with light, the generation of a work solely constructed of light; sound, image, and presence. It surpassed the language barrier by speaking in a single, common tongue, a frame of reference, valid and constant to all things, till the end of time.
FIGURES
Figure 2
Sir Arthur Stanley Eddington (1882–1944)

Figure 6

Figure 7
Figure 9
AQUA ECHO

PERFORMANCE PHENOMENA

Center For Advanced Visual Studies W11 Massachusetts Institute of Technology
6 May–7 May 1987
8:15 pm. and 9:15 pm.

SHAWN ALAN BRIXEY
LAURA KNOTT DANCE CO.

Sponsored in part by The Council For the Arts at MIT
Fig. 369. Variations of skeleton structure of hexagonal prism.
SKY CHASM
PERFORMANCE PHENOMENA
documenta 8
July 10-12 1987
KASSEL, FRG

SHAWN ALAN BRIXEY & LAURA KNOTT

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Figure 27
Figure 28
ILLUSTRATION DESCRIPTION

"Photon Voice"

Figure 1  Albert Einstein, Burndy Library / Courtesy of AIP / Neils Bohr Library.

Figure 2  Alexander G. Bell, Photophone, Nature, MacMillan & Co., London, February 19, 1880.

Figure 3  Thomas Young (1773-1829), Young’s drawing of two source interference pattern, Paul Tipler, Physics, Worth Publishers, New York, 1976, pg. 128.


Figure 5  Sterns, Gerlach Device, for orienting particles. Dancing Wu Li Master, Gary Zukav, William Morrow and Company (1979), pg. 300.

Figure 6  Sir Arthur Eddington; and solar eclipse photograph; displacement of a star’s actual light path due to the strong gravitational field, curvature of space. Bettman Archive Inc. Einstein’s Legacy, Julian Schwinger, Scientific American Library, New York (1986).

Figure 7  “Photon Voice” Poster Description: Desert Sun / Desert Moon, Ca. vs. M.I.T. Project. Opening event of 1986 Skyart Conference Photo Otto Piene. (Smithsonian World Film Crew in background.)

“The bright, star shaped device to the right of center is for stereo sound transmission via a ‘modulating heliostat array’ of swivel mounted, mirror mylar covered speakers. Vibration encodes wavefronts of sound into sunlight beamed down range to receiving station (lower center). ‘Optical stereo demodulator’ is a personal cassette stereo re-wired using photo-voltaic cells to count incoming numbers of photons to reconstruct stereo sound from sunlight. The four large mirrors (directly center) are a 25 square foot array aligned to track sunlight for three minutes each day. The mirrors reflect solar “radiation pressure” down range (far right) to first a condensing lens, 41” x 30” fresnel. Behind the fresnel lens is a hooded apparatus which contains an array of condensing lenses
and a 250 ml evacuated glass flask. Pencil thin beams of sunlight enter the flask. The radiation pressure interacts with microscopic graphite crystals, levitating them. Small, dense, spiralling galaxies of graphite crystals dance, echoing Laura's choreographic movement in real time. (far left) Image transmission is accomplished using a series of fresnel lenses of different focal length, combining to create a camera obscure type inverted image of Laura's dance in the sky.”

Figure 8  Detail of “Variable Reflector Modulating Heliostat Array”  
“Photon Voice” 1986  Photo: Donna Coveney.

Figure 8.1  Detail of vibrating surface with mercury, analogous to mirrored mylar on the “variable reflector modulating heliostat arrays.”  

Figure 8.2  Detail of reflected light patterns from modulating mirrored surface.  
Ibid. 107.

Figure 9  Amorphous and polycrystalline, solar cell, diagram, *Scientific American*, Dec. 1986, pg. 89.

Figure 10  Graphite particle levitation, individual frame from 16 mm Microscopy film footage (for Smithsonian World) Magnification 100x  Photo: Shawn Brixey.

Figure 11  The Sc galaxy NGC 5194 (M51) and its irregular II companion photographed with the 5-M telescope. *Exploration of the Universe*, George O. Abell, Saunders College Publishing, New York: 1982, pg. 605.

Figure 12  The open star cluster M67 (NCG 2682) in cancer photographed with 5-m telescope (Caltech / Palomar Observatory) Ibid. pg. 494.

“Aqua Echo”

Figure 13  “Aqua Echo” Poster:  Photo and Design, Shawn Brixey.

Figure 14  Detail Plate of Snow Crystals, *Snow Crystals*, W.A. Bentley, Dover Publications, New York (1931).


Figure 16  Detail of splintering process, nuclei storms. Ibid., pg. 206.

Figure 17  The freezing of water on organic materials. Ibid., pg. 226.


Figure 18.1  Ibid., pg. 69.

Figure 18.2  Ibid., pg. 169.

Figure 19  Stroboscopic photographic of dendrite growing on an individual ice crystal, *Snow Crystals*, U. Nayaka, Harvard University Press, Cambridge, MA (1954).

Figure 20  Detail of various ice crystal growing in a controlled stepped temperature gradient. *Physics of Clouds*, B.J. Mason, Clarendon Press, Oxford (1971), pg. 261.

Figure 21  Supercooled soapfilm detector, for determining atmosphere nuclei count, tiny ice crystal begin to grow on the film until they reach another crystals boundary. Ibid., pg. 271.

Figure 22  Detail of the growth of crystals on supercooled soap film. Ibid., pg. 272.

Figure 23  Etching of surface through sublimation. Ibid., pg. 273.

Figure 24  Detail of "Aurora Ice Crystal" type, in white light and polarized light. Ibid. pg. 345.

Figure 25  Photograph of electrical discharge through water, forming ripping waves. *Demonstrations in Physics*.

Figure 27  “Sky Chasm” postcard, for documenta 8. Photo: Shawn Brixey and Laura Knott, 1987.

Figure 28  Audible holographic image in the process of time dialation, Photo: Shawn Brixey.

Figure 29  Time averaged hologram, recording the surface of a flat circular disk under vibration, the same vibration produces a standing wave which is read by the optics of the audible interferometer as time dialation. *Holographic Interferometry*, Charles Vest, Wiley and Sons, New York 1979.

Figure 30  Detail of a single “Interference Transmission Array” from “Sky Chasm,” testing the day time apparatus with Laura’s movement, photo: Donna Coveney, 1987.
Footnotes


16. Johannes Keppler, Ibid.


* All definitions are composites of:


Bibliography

Selected Physics


Selected Relativity


Selected Quantum


Selected Experiments


Selected Optics


Selected Astronomy


Selected Ice and Crystal Physics


**Selected Holography and Interferometry**


**Selected Art**
