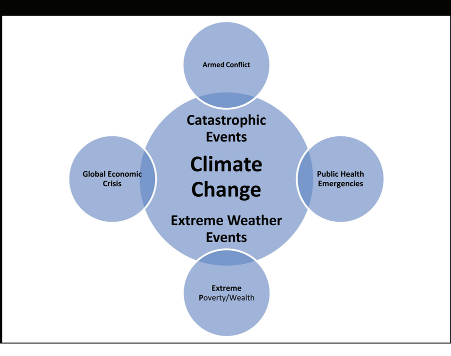
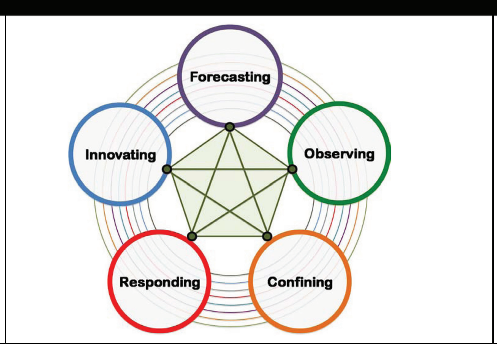
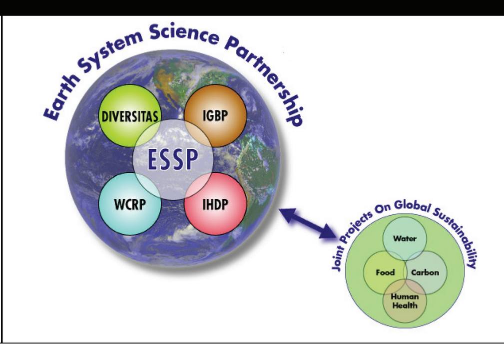
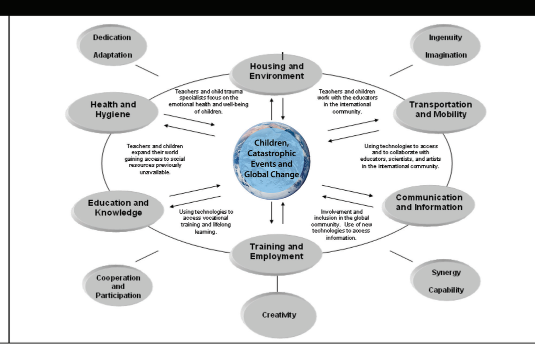








Integrating The Social Sciences And Humanities In Earth System Science To Address The ICSU/ISSC Grand Challenges

The Planet Under Pressure Requires Institutional Reforms in the Academy

This 11-year transdisciplinary study draws on the physical and social sciences and humanities. The ICSU/ISSC Grand Challenges question has become critical to the study:

How can timely actions be undertaken at unprecedented and multiple geographical and geopolitical scales, where the nature and scale of the issues involved means that the actors have widely differing—and—disconnected values, ethics, emotions, spiritual beliefs, levels of trust, interests and power?

In science there are no absolutes and in social life nothing is certain. When people arrive on the scene, where there is order there is disorder, and while many social events can be anticipated and explainable, most are unpredictable.

At the present time we are not well prepared for extreme weather events, for global economic instability, for the impact of food and water shortages, for public health emergencies, for industrial disasters, for natural disasters, or for the social and political unrest and armed conflict that is often associated with these extreme conditions.

The increasing scale and intensity of these complexly interrelated disasters challenges our capacity to adequately respond, either in the aftermath of the events taking place or in the recovery phase of disasters.

Nevertheless it is imperative that we ask the question, *and* that social scientists and scholars in the humanities work with Earth system scientists to address it. Social scientists and scholars in the humanities cannot stay in the margins of Earth system science, we have to join in.

At the present time social scientists are not even a footnote on the page.

In addition to new collaborative projects it is of critical importance in the vital transdisciplinary configuration that we reflect upon the research we have done and ask how our research findings advance our understandings of people and the planet. "What insights can we share?"

The growing capabilities of Earth system scientists to predict anthropogenic change, provides a nucleus for hope, but only if social scientists and scholars in the humanities find ways to participate in the endeavor.

The institutional reforms advocated by ICSU have the potential to create opportunities for greater understanding of not only the impact of people on Earth system functioning, but also of the impacts on people of the Earth system changes that are taking place. The current organization of research institutions creates, maintains and perpetuates divisions.

At the 2010 Visioning at ICSU in Paris, Johan Rockström spoke of the need for a fundamental change of structure and a stronger engagement in communication and capacity building that is more true to the societal needs in the world. He spoke of "a new effort to serve society," "new institutional frameworks," "greater consolidation," and "an investment in integrated science." Scientists at the forum discussed the large knowledge gaps within and between disciplines, and the need for transdisciplinary research was widely agreed upon –although there was also agreement that basic geo and biophysical Earth science research should be both supported and continued without being impeded by any reorganization efforts.

It is imperative that basic research continues, but within broader frameworks that take into consideration transdisciplinary perspectives. The non linear interrelationships between atmospheric and ecosystem stressors and human activity brings into sharp focus the supercomplexity of the relationships between the physical, biological and social sciences. Any global sustainability efforts will be highly dependent on the ability of all those who participate to take into consideration the professional challenges of working with participants who hold different views of science and, quite possibly, of humanity.

Even the suggestion of such systemic institutional change shakes up the academy. It challenges our understandings of the status quo, encourages us to rethink our positionalities within institutions and our relationships with other scientists, and challenges our conceptions of the endeavor we call "science." Implicit in the conception of transdisciplinary research is the co-production of knowledge.

Transdisciplinary research in Earth system science requires consideration of complementary and contradictory paradigms and metatheories—ideological and theoretical presuppositions — which are philosophically grounded in different views of science with different histories and traditions.

Thus, we will have to reexamination the interconnections between the social, cultural, psychological, biological, and physical sciences, so that new questions can be asked, new understandings gained, and actions taken. To foster collaborative research networks that are truly global in scope transdisciplinary research will require the merger of disciplines and the establishment of research communities which include both physical and social scientists. This will create new conceptual spaces for further scientific thinking beyond the possible perspectives that can be gained from within any single discipline or paradigm.

"We're all working on the edge of our disciplines," a scientist said at the 2010 ICSU Visioning Forum in Paris. Earth system scientists work in the margins, in the spaces between disciplines, centrally dislocated, conducting research while coping with metaworries about metatheories. Many researchers in the social sciences are similarly situated. Inevitably, problems arise from working in complementary and contradictory paradigms, where there are concerns about: (1) reductionism and expansionism (2) questions about the super-complexity of research studies (3) worries about systemic risk.

Colleges and universities are not set up to support them – or to support the participation of social scientists in Earth System transdisciplinary researcher endeavors.

Responding to the Planet Under Pressure Creates Profound, New, and Historic Possibilities for Physical and Social Scientists to Work Together

At the 2010 Visioning Paris, Johan Rockström said, "There have been great advances in science. As scientists it is fundamental that we move towards institutional frameworks to support research for a more sustainable world." A greater difficulty than changing the organizational structures of universities – if that's possible – is changing the *insularity* of social and physical scientists' disciplinary ways of being –*seeing and knowing* – within the institutions to which they belong.

Rockström talked of "something profound and new" and of an "historic opportunity." What *is* profound and new *and* historic is the possibilities of finding ways for physical and social scientists to *work together*. But given the inadequacies of social science engagement where do we start? What are social scientists supposed to make of "non-linear social and ecological dynamics, interactions, thresholds and tipping points"? How do scientists in the geobiophysical sciences begin to talk with social scientists about their concerns that will need a very strong emphasis on multiple, multi-layered socio-geographic perspectives?"

The bottom line is that *researchers in the physical and social sciences must talk to each other, read each other's research, and collaborate in research projects so they can imagine science differently* – thus expanding the possibilities of transdisciplinary research. But there's a caveat.

"We see the lives of others through lenses of our own grinding and they look back on ours through ones of their own," Clifford Geertz (1984), the renowned Princeton anthropologist writes, in his seminal article on the vituperative attacks on anthropology by other social scientists.

Another difficulty that must be addressed is the disagreements and dissonance *within the social sciences.* The scientific evidence for the great acceleration is rock solid, but most social scientists remain on the periphery, are not engaged at all, and/or are resistant to any invitation to participate in intellectual activities that stretch them beyond their disciplines, paradigms and favored lines of research, many preferring instead to remain caught up in local squabbles, and lost-in-the-moment contentious arguments.

At the social science conferences there is no mention that what is happening to the planet is outpacing the response. In social science journals there is scant mention that our current path is unsustainable, or that immediate action must be taken to change the global impact of people on Earth System functions. There is no sense of the "urgency" being "so daunting" that the scientific community needs to regroup, reorganize, and restructure to meet the challenge.

Discouraging at best ---given we don't have a century to wait. *For social scientists their disciplines are like countries and their scholarly and professional identities are steeped in the ideologies and mythologies of the paradigms to which they belong.* But perhaps it is our propensity for argumentation, *perhaps* it is *what* we argue about – *what it means to be human* –that makes the debates so agonistic and antagonistic.

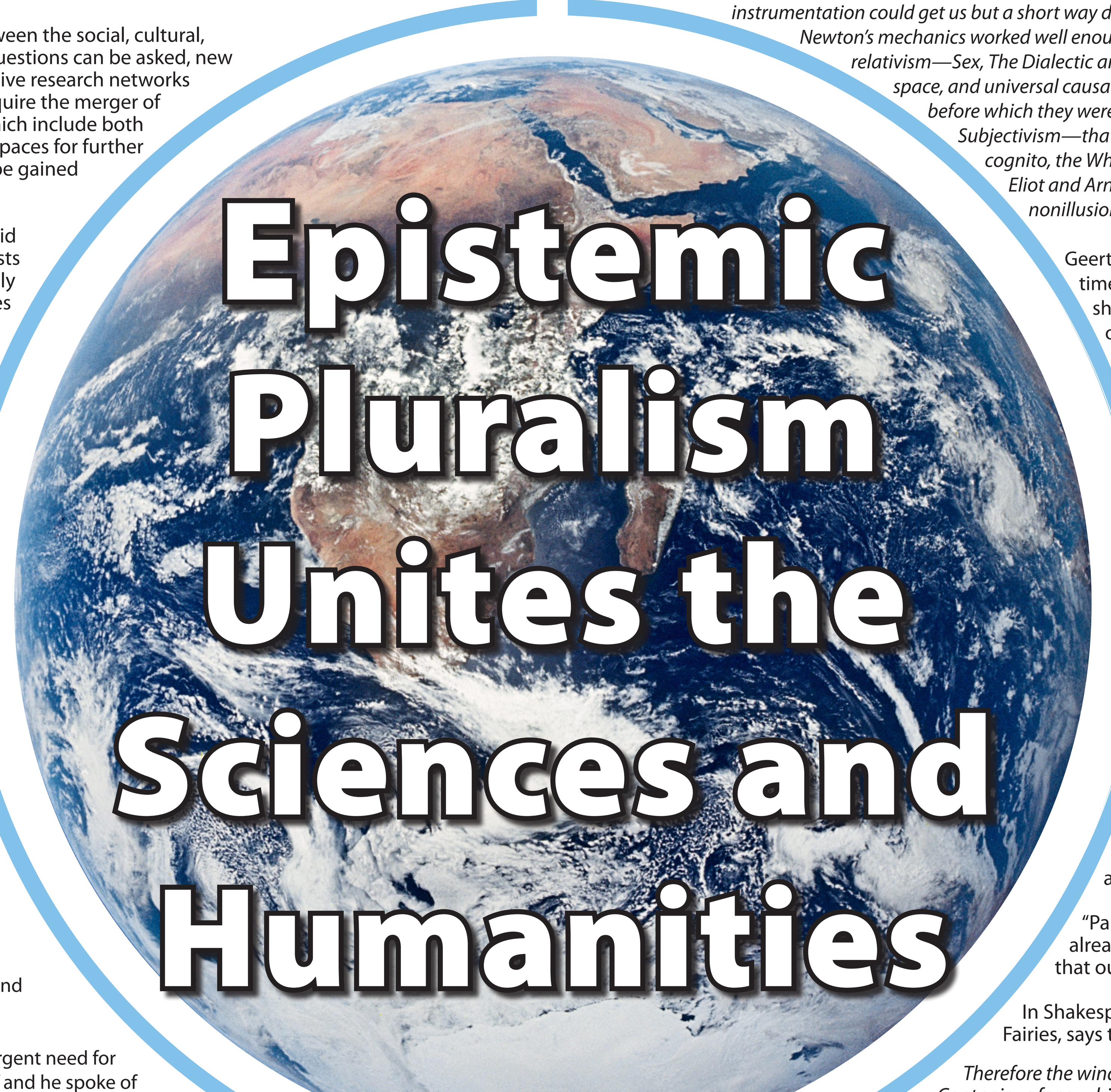
How can timely actions be undertaken at unprecedented and multiple geographical and geopolitical scales, where the nature and scale of the issues involved means that the actors have widely differing—and—disconnected values, ethics, emotions, spiritual beliefs, levels of trust, interests and power?

Perhaps, counter-intuitively, the disarray of the social sciences and the cacophony of positions and dispositions actually create opportunities for the QoQ to be addressed.

Before scientists in the physical sciences despair at the ambiguity, indeterminacy and disarray in the social sciences and the cacophony –the noise on the page-- the disagreements and dissonance within the social sciences -- as well they might-- Geertz opens the door to the connections that already exist between the social and physical sciences that provide a way of thinking about possible collaborations in transidisciplinary science. Once again, Geertz is worth the read: *It is, so I think, precisely the determination not to cling to what once worked well enough and got us to where we are and now doesn't quite work well enough and gets us into recurrent stalemate that makes a science move. As long as there was nothing around much faster than a marathon runner, Aristotle's physics worked well enough, Stoic paradoxes notwithstanding. So long as technical instrumentation could get us but a short way down and a certain way out from our sense-delivered world, Newton's mechanics worked well enough, action-at-a-distance perplexities notwithstanding. It was not relativism—Sex, The Dialectic and The Death of God— that did in absolute motion, Euclidean space, and universal causation. It was wayward phenomena, wave packets and orbital leaps, before which they were helpless. Nor was it Relativism—Hermeneutico-Psychedelic Subjectivism—that did in (and has to the degree they have done in) the Cartesian cognito, the Whig view of history, and "the moral point of view so sacred to Eliot and Arnold and Emerson." It was odd actualities—infant betrothals and nonillusionist paintings—that embarrassed their categories (p. 275).*

Geertz writes of old triumphs becoming complacencies, and one-time breakthroughs being transformed into road blocks which are shaken up by odd actualities. It is the gut wrenching experience of being there when catastrophic events take place that will draw them into collaborative work with physical scientists.

For the social scientist "being there" makes Eric Chivian and Aaron Bernstein's *Sustaining Life: How Human Health Depends on Biodiversity* essential reading, but without the research in Steffen and his colleagues' *Global Change and the Earth System: A Planet Under Pressure*, there can be little understanding of what's happening to the planet.



Observations, Models and Epistemic Pluralism in Research on the Planet Under Pressure

In Earth System science an *epistemic problem* is the inherent dualities of "pure and applied science". The idea of "basic and applied research" has long been the received orthodoxy, but in the *quest for new knowledge towards solutions* the allocation of the social sciences to the "applied side" is problematic. "New Perspectives and research are needed to *understand the complex relation between global transformations of social and natural systems*," Biermann and his colleagues (2010) write. "Innovative research is needed also to analyze political options to govern sustainable development – taking into account not only political effectiveness and efficiency but also global and national justice and equity".

At the 2010 ICSU Visioning in Paris, Rockström emphasized the urgent need for "more deep social science on global change and natural science," and he spoke of the critical imperative for "investment in integrated science." He stressed that global observation is stronger when "all the elements are wrapped up in a more integrated way."

Rockström spoke of the Grand Challenges and of the "bringing two worlds together" as a "potential source for a weakness" inherent in the document – expressed by the participant at the meeting who was concerned by the absence of culture in the presentation of the Grand Challenges. He stressed the need for "clarity of defined research priorities" but then acknowledged that the research priorities included "a mixture in terms of research things," of "action oriented things that aren't environmental but political" that needed "more clarity in defining."

When the dynamic complexity of the planet is combined with the dynamic complexity of human life on the plant even the most advanced Earth System models are questionable. The complex relationships between people and the planet are not static or unidirectional. What we do changes the planet just as it changes us. Both the planet and people are probabilistic and not deterministic, nothing is ever "settled". Thus, in science, even the most dynamic, interactive, non-linear, multimodal models that scientists build are not actual representations of real systems. In the dynamic observational sciences, integral to multiple disciplines, *epistemic pluralism* opens up possibilities for new models to be developed and new insights to be gained.

Owing more to Vico and Montaigne than to Descartes, within the interpretivistic social sciences, *scientific rigor* is highly dependent on disciplined, systematic observations. Clifford Geertz, the renowned Princeton anthropologist, called it *"thick description",* and such scholarship is a lifetime pursuit for many researchers whose scientific endeavors require *close observation of human societies* in family, community, institutional, and other organizational settings.

It is in the *situatedness* of human activity, the *embeddness* of social practices, how practices are constitutive of socio-semiotic systems, and events are symbolic of particular discourse communities, which many researchers, across the social sciences, endeavor to observe, document, and explain. The caveat is that observing in the physical world is not the same as observing in the social world. The observations of researchers in the physical sciences are qualitatively and quantitatively different than the observations of researchers in the social sciences. Nevertheless, *epistemic pluralism* expands our understandings of transdisciplinary research, and by so doing changes the possible meanings of the question of questions and our possible responses to it. Once again the QoQ:

How can timely actions be undertaken at unprecedented and multiple geographical and geopolitical scales, where the nature and scale of the issues involved means that the actors have widely differing—and—disconnected values, ethics, emotions, spiritual beliefs, levels of trust, interests and power?

Any transdisciplinary response must begin with an examination of the observational data—both physical and social—taking into account the *situatedness* and the *embeddness* of the phenomenological, the functional and the physiological (physical and biochemical) *in both the natural and social worlds*. Deep Science x Deep Science, it's our only chance to respond to the great acceleration.

Once scientists have collected their observations – whether data from space stations or from human communities—they have to do something with them. In science the *construction of models based on observational data has long been integral to the development of new knowledge, predictions, effective decision making, and action.*

The supercomplexity of this challenge to the Earth System Science is presented in the ICSU Grand Challenges document by the following sentence: *The observation, data preservation and information systems required need to: encompass both natural and social features; be of high enough resolution to detect systematic change; assess vulnerability and resilience; include multiple sources of information (quantitative and narrative data and historical records); provide information about both direct drivers of change and indirect drivers; involve multiple stakeholders in the research process; support effective decisions at global and local scales; be formally part of adaptive decision making processes; provide full and open access to data; and be cost effective.*

We know of the great acceleration through the vast wealth of data and the efforts of thousands of scientists and the models they have developed based upon the sheer genius of their observations. But the refinement of modeling capability in Earth System Science is tempered by the dynamic complexity, the *epistemic pluralism*, of the social world. The QoQ confounds the modeling process. There is no possibility of algorithmic certainty. Models are vulnerable to too many sociopolitical and socioeconomic kicks. Models can provide useful information – including warnings -- but not answers.

"*All models are wrong, some are useful*," George Box, the renowned statistician is often quoted as saying. Boé, Hall and Qu (2009), in an article which focuses on the rapidly changing Arctic Climate, quote Box, and write, *"We could add that many models—each wrong in a different way—can collectively be useful as a nearly perfect one, as long as observations exist to guide interpretations of their predictions".*

The Humanities are Important to the Development of Models of Non-Linear Dynamics and Thresholds of the Planet Under Pressure

Stories of our mortality run deep in human history – in every culture in every society. Similarly, the human destruction of the planet is a narrative loop that has reoccurred in oral stories and literature through the centuries and millennia.

"Paradoxically, before scientists tell us the sky is falling, we already know what is happening to the planet. It's an old message that our actions can be disastrous and have huge consequences.

In Shakespeare's *A Midsummer Night's Dream*, Titania, the Queen of the Fairies, says to Oberon, the King of the Fairies:

Therefore the winds, piping to us in vain, As in revenge have sucked up from the sea Contagious fogs, which, falling in the land, Hath every pelting river made so proud That they have overborne their continents. The ox hath therefore stretched his yoke in vain, The plowman lost his sweat, and the green corn Hath rotted ere his youth attained a beard. The fold stands empty in the drowned field, And crows are fatted with the murrain flock.

Hurricanes, tsunamis, heavy rains causing rivers to burst their banks, drowning livestock, destroying crops, pollution of contagious fogs, with birds growing fat on the diseased carcasses of dead sheep – it's today's story, an Earth science narrative that continues inexorably.

The human mortals want their winter here. No night is now with hymn or carol blessed. Therefore the moon, the governess of floods, Pale in her anger, washes all the air, That rheumatic diseases do abound. And thorough this distemperature we see, The seasons alter: hoary-headed frosts Fall in the fresh lap of the crimson rose, And on old Hiems' thin and icy crown An odorous chaplet of sweet summer buds Is, as in mockery, set. The spring, the summer, The childing autumn, angry winter, change Their wonted liveries, and the mazèd world By their increase now knows not which is which And this same progeny of evils comes From out debate, from our dissension; We are their parents and original.

In our time, the bewildered (mazèd) world no longer knows the difference between winter (old Hiems'), spring, summer and fall. Weather patterns are more erratic and extreme. All life forms – bees, bats, birds, frogs, and children – have become increasingly susceptible to bacterial, viral, and fungal illnesses, some old and some that have not been known before. Common ailments such as rheumatic diseases flourish as do the illnesses caused by toxic stress that change our body chemistry and disorder cortisol metabolism, creating greater vulnerability in children. And, all progeny of evils originates from us, from human activity, from our enterprise, from our debate, from our dissension, the local gathered into the global, involving people of widely differing and disconnected values, ethics, emotions, spiritual beliefs, levels of trust, interests, and power – on a scale so vast it is beyond our capability to comprehend, except in fiction.

A few lines in a Shakespearian play convey the same message as any Earth System heavy tome. Plagues, pestilence, fires and flood, life and death, the struggle against adversity are played out in different ways across the ages. Shakespeare, writing at the time of Vico and Montaigne, reminds us of what we have forgotten, helping us remember, and brings us to the present day and the situatedness of our minds and bodies in the natural world.

In Earth science human experience, philosophy, and literature are intimately connected. *In Daughters of the Moon*, Italo Calvino (2002) connects them directly:

The road petered out in a hilly area with little valleys, ridges, hills and peaks; it was nor the contours of the land that created the bumpiness, but rather the layers of things that had been thrown away: everything that the consumerist city expelled once it had quickly used it up so it could immediately enjoy the pleasure of handling new things, ended up in that unprepossessing neighborhood.

Over the course of many years, piles of battered fridges, yellowing issues of Life magazine, fused light bulbs had accumulated around an enormous junkyard of cars. It was over this jagged, rust territory that the Moon now loomed, and the swatches of beat-up metal swelled up as if lifted by a high tide. They resembled each other: the decrepit Moon and that crust of the Earth that had been soldered into an amalgam of wreckage; the mountains of scrap metal formed a chain that closed in on itself like an amphitheatre, whose shape was precisely that of a volcanic crater or a lunar sea.

In the midst of the things that had been thrown away lived a community of people who had also been thrown away, or marginalized, or had thrown themselves away of their own volition, or had got tired of running all over the city to sell and buy new things that were destined to go out of date immediately: people who had decided that only things that had been thrown away were the real riches of the world.

That morning the city was celebrating Consumer Thanksgiving Day. This feast came round every year, one day in November, and had been set up to allow the shops' customers to display their gratitude towards the god Production who tirelessly satisfied their every desire".

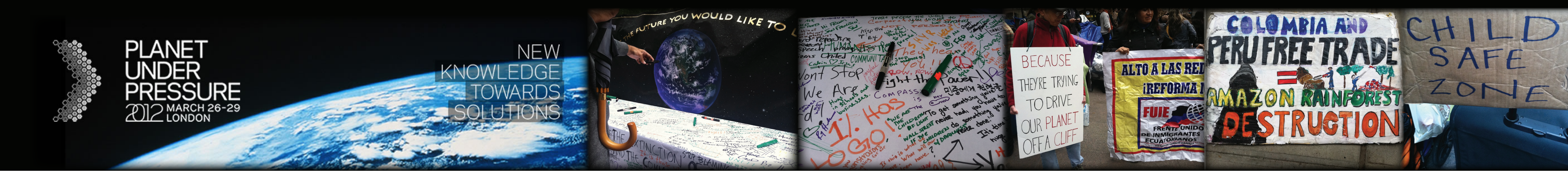
The rest of the story is worth reading – the moon is reborn but not the Earth, and Calvino imagines the world as if it could be otherwise, without the junk and wreckage of discarded lives "*we realize that now is when life begins,*" he writes, *"and yet it is clear that what we desire shall never be ours".*

Reading *The Daughters of the Moon* while studying Earth system science changes the story. But it is not only literature that is changed by science, *we are changed, and in that changing science changes too*—the depth of our understandings, our vision and our insights – lifting the curtain on the dynamic complexities of interrelationships between our social and physical worlds.

Calvino helps us get it. Language is always central to his thinking. *"Words,"* he writes, *"like crystals, have facets and axes of rotation with different properties, and light is refracted differently according to how these crystal-words are orientated".* He writes of the importance of living in a world where science, philosophy and literature constantly challenge each other. "Literature," he tells us, "breathes philosophy and science but keeps its distance and dissolves, with a slight puff of air, not only theoretical abstractions but also the apparent concreteness of reality". Calvino writes that he is alluding to "that indefinable region of human imagination" which he, himself, sets free.

Can Science Save Us? The Great Acceleration From Adaptation to Transformation or *Annihilation*? **What Happens When Life as We Know it Ends?**

Denny Taylor, International Center for Everybody's Child, Hofstra University



Unpackaging Human Enterprise And Communicating With The Public

Can Science Save us if Science has Outpaced the Governmental Capacity to Respond to What's Happening to the Planet, or has What's Happening to Governments Outpaced Science?

This 11-year transdisciplinary study draws on the physical and social sciences and humanities in response to the overwhelming scientific evidence that people are changing the planet.

Based upon the empirical evidence, if we wait for a response from global leaders and policy makers it will be too late. Governments must act. Reducing carbon dioxide (CO_2) will require legislation, but this will not be enough to reduce our transgression of planetary boundaries which places humanity at grave risk.

There are also multiple social tipping points that urgently need to be addressed, including global changes in financial regulation. Immediate action must be taken to stop speculative trading in vital commodities such as oil and food which causes extreme volatility in the market. Gambling on the price of food is catastrophic for vulnerable populations, counted in the billions, for whom the rapid rise in the price of food is a matter of life or death. When food prices rise rapidly there are cascading effects, including a rise in social unrest and armed conflict, public health emergencies, the internal displacement of people, and massive migrations, all of which lead to further destruction of ecosystems, accelerating climate change, and diminishing the essential conditions for human life as we know it.

The call from the international scientific community is for scientists to *"deliver knowledge", "build the capacity to deliver solutions", "effectively deliver end-to-end environmental services", "to provide new insights and solutions", "to solve real world problems", and most recently to deliver "actionable science".*

This begs the question: *Can science save us if science has outpaced the governmental capacity to respond to what's happening to the planet, or has what's happening to governments outpaced science?* It is a version of the question Hannah Arendt first asked, and one of the most prescient questions scientists are attempting to address.

Can we in this time of great danger and uncertainty, undertake global initiatives in response to climate change and ecological destruction of the planet without considering the *super complexity* of the *non-linear, dynamic interrelationships* between the global economic crisis, extreme poverty and wealth, armed conflict, and public health emergencies? Is it possible to address any of these interrelated catastrophes without also taking into consideration *the great acceleration* in the industrialization of the planet? Or, *to act* without recognizing that a rapid increase the number of people from 7 billion to more than 9 billion by the middle of this century will lead to an unprecedented increase in natural and human disasters? Will we adapt? Will human societies be transformed? Or, increasingly become sites of civil unrest and armed conflict?

In response to the uncertainty about the future, many scientists are repositioning themselves, moving from highly specialized, disciplinary research to interdisciplinary research which creates opportunities for researchers to address the complexity of the Earth System changes taking place. Still other scientists are taking a more radical stance and engaging in transdisciplinary scholarship that brings together the physical and social sciences in new and dynamic ways. Now researchers in the physical scientists are re-negotiating their role in the society by asking:

How can timely actions be undertaken at unprecedented and multiple geographical and geopolitical scales, where the nature and scale of the issues involved means that the actors have widely differing—and—disconnected values, ethics, emotions, spiritual beliefs, levels of trust, interests and power?

The question comes from the International Council for Science's (ICSU) 2010, Grand Challenges document. It is the question that hides behind the question Can science save us?, the *Question of Questions*, the QoQ that has dogged people long before Montaigne. It is the QoQ that politicians have abysmally failed to answer, and Earth System Scientists are only just beginning to address.

Such enduring questions are not the forte of Cartesian science. Descartes, Newton, Hobbes, the belief that the physical world *and man* can be rationality understood through mathematical reasoning and formal argumentation, leaves little room for strong emotions or for the violent and passionate manifestations of human behavior that are constitutive of the QoQ. Ideologies, values, and beliefs defy logic and reason and in a world divided into sovereign nations that are parsed into widely differing political, religious, ethnic and racial groups with disconnected values, ethics, emotions, spiritual beliefs, levels of trust, interests and access to power.

The QoQ has a long history in the social sciences and humanities, and provides an opportunity for social scientists and scholars to work collaboratively with scientists in the physical sciences.

However, for many social scientists, the pressing problems of today leave little time for such questions. But in the midst of their struggle to respond to the long term misery and degradation in human societies, massive upheavals and seismic shifts in human populations are taking place which could conceivably be one of many indicators of a *step change* in human history. The fallout from the future is happening now. The ways in which we think, conceptualize knowledge, and live our lives is changing fast, but not in ways that support human life on Earth.

The Self-Destruction of the Apparatuses that the Modern World has been Building up on a Planetary Scale

Will we adapt? Will human societies be transformed? Or will we be annihilated by our destruction of the planet? Has the great human project really failed? Unsettling as it may be, no one knows for sure. Practicing ventriloqy, politicians offer the reassurances of lobbyists and funders, while the public relations firms working for multinational corporations convince us that oil is green in the aftermath of BP, and that nuclear power is good in the aftermath of Fukushima. And in this way we are lulled into believing or wanting to believe that they speak the truth, until Sabu Kohso (2011), who was born in Okayama, Japan, shouts at us and shakes us up:

What has been happening in Japan since 3/11/2011 cannot be deemed merely a situation particular to a nation-state in the Far East, but unfortunately a new phase of human history, an opening toward an apocalypse, or a total transformation or both. It is a universal experience in the sense not only of its economic and environmental impact but also of the self-destruction of the apparatuses that the modern world has been building up on a planetary scale.

Many Earth System scientists agree with Kohso. In 2009, Johan Rockström and twenty eight Earth system scientists, including James Hansen and Will Steffen, identify nine planetary boundaries for human life on Earth. *"Transgressing one or more planetary boundaries,"* these scientists write, *"may be deleterious or even catastrophic due to the risk of crossing thresholds that will trigger non-linear, abrupt environmental change within continental- to planetary-scale systems".* The article is technical but the message is not. Rockström *et al.* state in the introduction, *"We estimate that humanity has already transgressed three planetary boundaries"* – 1) Climate Change; 2) Rate of Biodiversity Loss; and 3) Changes to the Global Nitrogen Cycle. They stress, *"Planetary boundaries are interdependent, transgressing one may both shift the position of other boundaries or cause them to be transgressed."* They write, *"There is significant uncertainty surrounding the duration over which boundaries can be transgressed before causing unacceptable environmental change and before triggering feedbacks that may result in crossing thresholds that drastically reduce the ability to return to safe levels".*

This transdisciplinary study is an attempt to put humans into the Earth system models, as Steffen encourages us to do, rather than positioning them –*us*—as an *"outside force"* perturbing the planet. It begins with an *"inside"* perspective of Earth system science, which is followed by the *unpackaging of human enterprise* to expose the *unearthing of people* that has taken place in the last four hundred years. The negative consequences of the protection of *"invested interests"* and the limited piecemeal and mechanistic responses of governments is examined, and is used to support the proposition that it is the inertia of governments, combined with the aggressive competition of geopolitical markets and the greed of global financial institutions, that provide the tipping elements for a step change for the planet and for humanity.

In *Climate Change 2009: Faster Change and More Serious Risks,* Will Steffen (2009) writes about *"putting humans into Earth system models".* He states, *"One of the most challenging research tasks ahead is to couple economic and social dynamics with the biophysical climate system in an interactive way".* For Earth system scientists the incompleteness of science without humanity is a huge dilemma. *"At present,"* Steffen writes, *"human actions are usually represented as an outside force perturbing the "natural" climate system via a greenhouse emission scenario, or climate is simply represented by a damage function related to temperature embedded in a much more complex economic model. Achieving a balance between the human and biophysical components of a global-scale model has proven difficult".*

When people arrive on the scene all complex systems become ambiguous, and models can be thrown off by human activity. Steffen tries to address this when he writes, *"In terms of human dynamics, a challenge for future modeling efforts is to capture the complexity of the ways in which societies are responding to climate change and will do so in the future. New approaches aimed at meeting this challenge include massive agent-based modeling, social network theory, game theory, evolutionary psychology and complex systems theory, or some combination of these".*

But all of these approaches are inadequate, and none of the social models have the predictive capability of physical models. Just as in science there are no absolutes, in social life nothing is certain. It is the nature of humanity that where there is order there is disorder, and while many social events can be anticipated and explainable, most are unpredictable. At the present time we are not well prepared for extreme weather events, for global economic instability, for the impact of food and water shortages, for public health emergencies, for industrial disasters, for natural disasters, or for the social and political unrest and armed conflict that is often associated with these extreme conditions.

Without the support and backing of the World Superpowers how *"timely"* will the *"actions"* be? What chance will scientists have to provide new insights and solutions to solve real world problems if the research is delivered to the U.S. Congress, but rendered ineffective by the irrational ideological gridlock of fractious partisan politics, and the deep associations of politicians with corporate lobbyists who represent the global financial institutions and multinational corporations that have become immensely rich on the backs of the people and at the expense of the planet?

The *unpackaging of human enterprise* that has *unearthed people* will take the efforts of scientists and scholars in the humanities working together to expose the negative consequences of the protection of invested interests by governments, which in turn are compromised by the aggressive competition of geopolitical markets and the greed of the global financial institutions, that provide the tipping elements for a step change for the planet and humanity.

In the spirit of Stephen Toulmin, it is going to take millions of people, of widely differing and disconnected values, ethics, emotions, spiritual beliefs, levels of trust, interest and power, working together in small groups and organizations, to ensure that billions of people do not lose their lives in the struggle to survive.

The ICSU On-Line Global Visioning Consultation Which took Place in August, 2009, and was a Precursor to the ICSU Visioning Open Forum in Paris in 2010.

In *Science*, July 17, 2009 Walter Reid, Catherine Bréchignac, and Yuan Tseh Lee write *"In the past, a small group of scientists would be charged with determining the most pressing research questions,"* they explain. *"Now, given the urgent need to confront human-induced global environmental change and the imperative to focus our scientific resources, we need to spread the widest possible net to make sure that the world's scientists will be addressing the questions that are the most critical".*

1016 scientists from 85 countries registered on the Consultation Visioning site. 323 research questions were posted. An analysis of the questions and responses revealed:

Many of the questions are embedded in ways of thinking – highly evolved disciplinary metatheories parsed into sub areas of specialization, each with signatures of practice so esoteric that only those within the sub-specialty can fully understand the significance, with many ways of knowing only actualized in situ through the actual doing of science.

Many of the questions address problems about the impact of human enterprise on the planet that require economic and political considerations and input from the public, as well as the social and physical sciences.

A few questions address the impact of human-induced change on vulnerable people and communities, but there are very few responses to these questions.

One group of questions calls for changes to take place in the *communicative interface between the scientific community, policy makers and the economic drivers of environmental and climate change, but there are few responses and no responses to the seven questions that follow.*

1. *"What are the main constraints to successful Earth System governance and what are our options for addressing these constraints in a timely, effective and accountable manner?"* asks Laszlo Pinter, director, Measurement and Assessment Program, IISD, Organization for Economic Co-operation and Development (OECD). (Q. 84)

The failure to make adequate, or any progress on Earth system issues such as poverty, ecosystem degradation or greenhouse gas emissions are related to society's inability to fully grasp the gravity of the situation," Pinter writes. *"We need to understand much more clearly what are the formal and informal barriers and biases in our policy mechanisms, public and private institutions (down to the role and interests of individual decision-maker) that help prolong unsustainable patterns of practices and behaviors."*

2. *How can the perceived imperative in market-economies for continuous open-ended economic growth, be reconciled with the need from a natural science perspective for the collective human impact on the biosphysical Earth system to be stabilized or decreased in order to sustain human well-being indefinitely?"* asks Robert Gifford, Department of Psychology, University of Victoria, Canada. (Q. 126)

"The conflict between economic and natural science perspectives addressed by this question is the ultimate driver behind the biosphysical Earth System issues that are of concern and have led to the emergence of the idea of Earth System Science," Gifford writes. *"Unless the conflict between the socio-economic drivers of national and international policy can be reconciled with biophysical (environmental) drivers of policy, solutions to earth system problems at the whole-system level are doomed to failure. It will take a long time for the two world views to become reconciled into a single workable approach. The sooner the ESS starts addressing the issue the better".*

3. *"How do we best understand the set of power relations between governments, corporations and civil society in a globalized world that keep us on unsustainable pathways? How do we transform these relations?"* asks Kamal Kapadia, Oxford Univeristy, Environmental Change Institute (ECI). (Q. 170)

"The key reason why we face so many ecological and human crises is because we are locked into developmental pathways sustained by certain power relations in this world," Kapadia writes. *"It is thus imperative to understand these relations in order to know how to tackle and transform them. Obstacles include diverse and conflicting conceptual models in the social sciences on how best to understand the operation of power in a globalized world. Obstacles also include a serious dearth of funding for such research, and an overwhelming importance given to economics amongst the social sciences (which does not address issues of power".*

4. *"What changes in policies (global to local) and human behavior will most strongly reduce human pressures on the planet's life support systems, and how can the scientific community influence their implementation?"* asks F. Stuart Chapin, Professor of Ecology, in the Institute of Arctic Biology at University of Alaska Fairbanks, whose research focuses on impacts of high-latitude climate change on ecosystem services and society. (Q. 246)

"Humanity has perhaps a couple of decades to radically reshape the relationship between society and the biosphere," Chapin states. *"This requires research on human perceptions and motivations as well as communications between scientists and society. Very little global change research is focused on these critical issues which will determine whether more basic research on global change will have any impact at all."*

On June 22, 2010, the International Council for Science (ICSU) held a Visioning Open Forum at UNESCO in Paris

For one day at this Visioning Open Forum, the curtain was drawn back on the workings of Earth system science as researchers from the geo biophysical sciences *and* a few from the social sciences gathered to talk across paradigms and disciplines about a draft of the Grand Challenges document which frames ICSU's plans for a new ten year Earth system global sustainability research initiative.

Questions were raised about the problems and limitations of interpretations of complex, dynamic, non-linear phenomena that do not take into consideration the artificial institutional divisions the sciences have constructed between the natural and human world.

Counter narratives emerged that reveal different understandings of Earth system science and of how to care for the planet and sustain life on Earth. No one contested the proposition put forth that while dangerous changes are taking place over time, abrupt changes are most dangerous. Cataclysm and cataclysmic were the descriptors used – ratcheting up the language used to describe the increase in concern for the potential for an unprecedented global disaster.

There was talk of the "urgency" being "so daunting" that there is a critical need for the scientific community to restructure to meet the challenges. "The tremendous message," as one scientist put it, "is that under the present institutional structures we will not be able to answer in time the research questions that confront us." "Scale," "focus," and "intensity" were used to describe the work that must be done. Scientists spoke of restructuring governmental agencies, funding agencies, research institutions, universities, and schools to respond in this time of global emergency.

Scientists spoke of restructuring governmental agencies, funding agencies, research institutions, universities, and schools to respond in this time of global emergency.

What these scientists were talking about was how to achieve a total *rethinking on a global scale* of the relationships between the *ecological* and the *social* – quite literally a repositioning of billions of people on the planet through a scientific revolution that even Thomas Kuhn might have found difficult to imagine.

Scientists agreed, as Will Steffen puts it in *Climate Change 2009: Faster change and More Serious Risks*, that *"One of the most challenging research tasks ahead is to couple economic and social dynamics with the biophysical climate system in an interactive way", and that "achieving a balance between the human and biophysical components of a global-scale model has proven difficult".*

The ISSC joined ICSU in confronting the dilemma of how to integrate the social, cultural, economic and political dynamics of human existence with geo biophysical global change research. Heide Hackmann, the Secretary-General of the Council, who stated that *"the integration of the social sciences and humanities is no longer a choice but a necessity"* in framing the global challenges that confront Earth system science. She spoke of *"creativity and energy"* and of *"the urgent need to reach out to the broader social science community".* She argued that it is *"not possible to underestimate the significance"* of the social sciences and humanities which can *"no longer be left in the margins".* She talked of including the social sciences in the *"framing process"* and of reaching out to the broader communities of the social sciences, *"to bring them into full partnership with the natural sciences"*, and within this context she spoke of *"mobilizing social scientists"* of *"more deep social science"* and *"more global observation".*

Descriptors that were frequently used by presenters and participant included: *"the co-creation of new knowledge", "large knowledge gaps in disciplines and between disciplines", "the integration of scientific expertise", "capacity building", "the bidirectional flow of information", and "research as a catalyst for cultural change".* Talk focused on "*the connections between people doing science and policy makers not working", "international cooperation", "creating social movements", and "deep transformations of societies".*

There was talk of the *"importance of reaching out to broader communities"*, the *"capacity for international collaboration",* and the *"use of multiple methodologies",* and of the *"lacking of mutual respect". "We're all working at the edges of our disciplines,"* a participant said, *"It's not an easy place to be".*

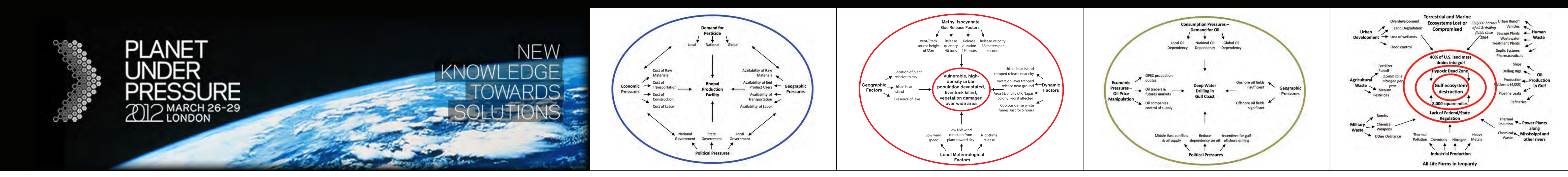
The conversation often turned to the inadequacy of communication between scientists and policy makers, and to the ineffectual presentation of the scientific evidence to the general public.
"Communication is central," a participant said, *"communicating science to the media".*

"We need for a clear vision of who the decision makers are," another participant said. *"There's an urgent need for policy response".*

There was general acknowledgement that the findings of Earth science research will not count for much unless: (1) the communicative practices in the interspace between science and parliamentary and governmental agencies are transformed; and (2) deep transformations in societies are achieved through social and political action.

Can Science Save Us? The Great Acceleration From Adaptation to Transformation or *Annihilation*? **What Happens When Life as We Know it Ends?**

Denny Taylor, International Center for Everybody's Child, Hofstra University



The Great Acceleration: The Anthopocene, Kicks, Dead Zones And Bridging The Abyss

In *Seventeenth Century and the Arts* Stephen Toulmin cautions that *"the more narrowly we draw the boundaries between our sciences, the less reliable they are".* Toulmin, advises us to *"reappropriate the wisdom of the 16th century humanists, and develop a point of view that combines the abstract rigor and exactitude of 17th century "new philosophy" with a practical concern for human life in its concrete detail".*

In the spirit of Toulmin this poster is designed to: (1) provide a conceptual framework for rethinking the relationships between physical and social scientists and scholars in the humanities; (2) to provide a starting point for the reconceptualization of school and university curricular divisions; and (3) to encourage the reengagement of the public in conversations about inseparable relationships between people and the planet.

Crossing fields, disciplines and paradigms, and working with different scales of documentation, this 11-year transdisciplinary study draws on the physical and social sciences and humanities in response to the overwhelming scientific evidence that people are changing the planet.

Five theoretically grounded conceptual metaphors have been constructed based upon the analysis of the data: *1) The Anthropocene; 2) Kicks; 3) Dead Zones; 4) The Great Acceleration; and 5) Bridging the Abyss.* These metaphoric representations draw on the humanities as well as the sciences, and each descriptor embedded in the graphics is supported by the analysis of key research within the specific fields and disciplines represented. Each Conceptual Metaphor is made up of a series of interrelated graphic representations constructed to address head on the issues of resilience, vulnerability, adaptation, and transformation across biophysical and social dimensions of anthropogenic global change.

Thus the visual representations can be thought of as *useful fictions* – an attempt to depict the interactions of phenomena, occurring on multiple temporal and spatial scales, happening simultaneously and sequentially, that are contingent and conditional, and highly dependent on the interactions of an infinite number of other phenomena, that have taken place, from deep time stretching through the present time and into the future.

Each Conceptual Metaphor: 1) combines the physical, biological, and social sciences with the humanities; 2) pulls from governmental, economic, and industrial sources, as well as social media; 3) provides transdisciplinary spaces that encourage situated engagement in research on climate change, biodiversity loss, ecosystem degradation *with* research on the impact of human enterprise on the planet as well as research on human vulnerability and resiliency; and 4) encourages the global science community to find new approaches to engage political leaders, government establishments, and the public sector—to prevent, mitigate, adapt and transform— but most importantly to act.

This poster focuses on the first conceptual metaphor: *The Anthropocene*.

The first graphic (figure 1.1) focuses on the potential for environmental and atmospheric stressors to cause the decline *and extinction* of bees, bats, birds, and frogs, and the critical concern of scientists and environmentalists about what is happening to these vulnerable and declining populations.

The observed factors identified in the research include: 1) poor nutrition and health; 2) abnormal growth and development; 3) decreased abilities to avoid predators; 4) decreased resistance to fungi, viruses and bacteria; and (5) shifts in reproductive timing. The factors are dynamic, complexly interrelated, and contingent and conditional on upon local, regional and global conditions. Tracie Seimon (2010) in *Acta Zoológica Lilloana*, provides a forum for frogs to speak for themselves:

We, the frogs, have continuously inhabited and evolved on this planet since the Devonian period some 350 million years ago. Our calls announce the beginnings of spring, we keep insect populations under control, we serve as toxic pollutant indicators for human health, we are bellwethers for environment change, we provide important medicine from the chemicals we produce, we help forest peoples hunt food with our poisons, we inspire art and poetry, and perhaps most importantly we inspire peoples to appreciate nature. Once a stronghold of 6200 species, we are now disappearing rapidly and scientists predict that nearly one third, or 2000 species, will disappear within this century. Our population declines have been attributed to a number of factors such as habitat loss, disease outbreaks, and environmental. In particular, the global spread of an emerging infectious disease, the pathogenic chytrid fungus Batrachochytrium dentrobatidis (BD), has resulted in population collapses and outright extinction among many amphibian taxa over the past 20 years. Now, we serve as indicators to humans of a more insidious slow-motion catastrophe playing out on a global scale. Human-created climate shifts resulting in increasing temperature and changing precipitation patterns are having large impacts on amphibian assemblages, population numbers, reproduction, behavior, phenology, and physiology. The climate changes are resulting in desiccation of ponds and aquatic breeding habitats, reducing leaf litter, reducing precipitation in cloud forests, all culminating in increased stress, disease outbreaks, and mortality.

In the **second graphic (figure 1.2)** birds, bees, bats and frogs are represented by the red dot at the center and their local habitat is circled in green. Now we can see the atmospheric and environmental stressors. The second graphic makes the case that biodiversity and ecosystem functioning are intimately connected, and that the negative impact of anthropogenic changes has serious and possible lethal consequences for assemblages, populations, and species. The brown bands around the second graphic represent the waste from human enterprise. To this image of our own detritus we can add the everyday toxicity of the run-off of contaminated water, which is compounded by environmental disasters, such as in the 2008 collapse of the coal ash pond in Kingston, Tennessee, in the U.S., and in Ajka, Hungary in 2010, when the dam holding back a vast reservoir of toxic red sludge from an alumina plant gave way, releasing a flood of processing chemicals and heavy metals, such as cadmium, cobalt and lead.

In Sustaining Lie: How Human Health Depends on Biodiversity, Eric Chivian and Aaron Bernstein (2008) make the case:

During the past fifty years or so, for example, our actions have resulted in the loss of roughly one-fifth of Earth's topsoil, one-fifth of its land suitable for agriculture, almost 90 percent of its large commercial marine fisheries, and one-third of its forests, while we now need these resources more than ever, as the population has almost tripled during this period of time, increasing from 2.5 to more than 6.5 billion. We have dumped millions of tons of chemical onto soils and into fresh water, the oceans, and the air, while knowing very little about the effects these chemicals have on other species or, in fact, on ourselves. We have changed the composition of the atmosphere, thinning the ozone layer that filters out harmful ultraviolet radiation, toxic to all living things on land and in surface waters, and increasing the concentration of atmospheric carbon dioxide to levels not present on Earth for more than 600,000 years. These carbon dioxide emissions, caused mainly by our burning fossil fuels, are unleashing warming of Earth's surface and of the oceans and a change in the climate that will increasingly threaten our health and the survival of other species worldwide. And we are now consuming or wasting or diverting almost half of all the net biological production on land, which ultimately derives from photosynthesis and more than half the planet's renewable fresh water.

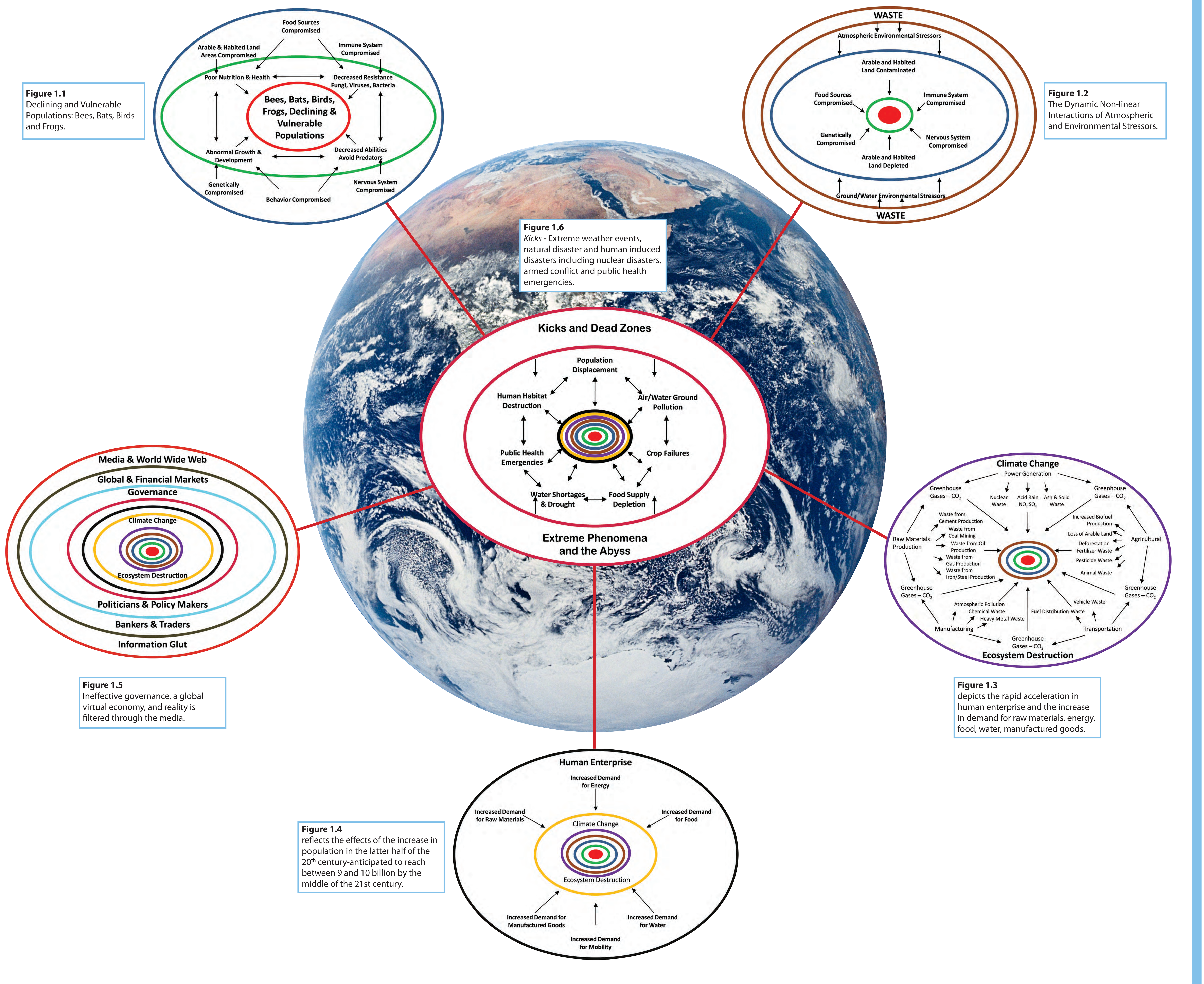


Figure 1.1
Declining and Vulnerable Populations: Bees, Bats, Birds and Frogs.

Figure 1.2
The Dynamic Non-linear Interactions of Atmospheric and Environmental Stressors.

Figure 1.6
Kicks - Extreme weather events, natural disaster and human induced disasters including nuclear disasters, armed conflict and public health emergencies.

Figure 1.5
Ineffective governance, a global virtual economy, and reality is filtered through the media.

Figure 1.3
depicts the rapid acceleration in human enterprise and the increase in demand for raw materials, energy, food, water, manufactured goods.

Figure 1.4
reflects the effects of the increase in population in the latter half of the 20th century-anticipated to reach between 9 and 10 billion by the middle of the 21st century.

Figures 1.3 and 1.4 depict the rapid acceleration in human enterprise and the increase in demand for raw materials, energy, food, water, manufactured goods. The graphic relies on primary data and a critical document analysis of research studies in the physical sciences – including reports by IGCC, NOAA, and primary research data available on websites, and presentations to the U.S. congress. Our focus here is on human enterprise, ecosystem destruction and climate change. It is important that we resist reading each descriptor as if it were a category separate from every other category, laminated or pasted on. The supercomplexity and infinite possibilities for Earth-biota "synaptic", could be described as the *infinity of semiosis*, of life on and of the planet. These figures show the planet domesticated for human use. Earth has been and *is being* transformed by the activities of people. We use the planet as an infinite source of products and services for our use alone and an infinite sink for our wastes. We are now consuming or wasting or diverting almost half of all the net biological production on land, and more than half the planet's renewable fresh water. The human driven changes that are taking place are a global threat that will deprive future generations of the life sustaining possibilities. We cannot live *in*dependent of nature—as if we own the planet.

Figure 1.5 reflects the effects of the increase in population in the latter half of the 20th century which is anticipated to reach 9-10 billion by the middle of the 21st century. In this figure research in the social sciences becomes increasingly significant. The negative consequences of the protection of "invested interests" and the limited piecemeal and mechanistic responses of governments is examined, and is used to support the proposition that it is the inertia of governments, combined with the aggressive competition of geopolitical markets and the greed of the global financial institutions, that provide the tipping elements for a step change for the planet and for humanity. Based upon the empirical evidence, if we wait for a response from global leaders and policy makers it will be too late. Governments must act. Reducing carbon dioxide (CO_2) will require legislation, but this will not be enough to reduce our transgression of planetary boundaries which places humanity at grave risk. There are also multiple social tipping points that urgently need to be addressed, including global changes in financial regulation. Immediate action must be taken to stop speculative trading in vital commodities such as oil and food which causes extreme volatility in the market. Gambling on the price of food is catastrophic for vulnerable populations, counted in the billions, for whom the rapid rise in the price of food is a matter of life or death. When food prices rise rapidly there are cascading effects, including a rise in social unrest and armed conflict, public health emergencies, a rise in the internal displacement of people, and massive migrations, all of which lead to further destruction of ecosystems, accelerating climate change, and diminishing the essential conditions for human life as we know it.

Jean Baudrillard (1993) in *The Transparency of Evil: Essays on Extreme Phenomena*, who makes us aware of our mindless intransigence and of the imminent dangers to our very existence. Baudrillard writes of *"an economy freed from 'Economics' and given over to pure speculation; a virtual economy emancipated from real economics (not emancipated in reality,) of course, we are talking about virtuality – but that is the point too: today, power lies not in the real but in the virtual; and an economy that is viral, and which connects with all other viral processes. … We forget a little too easily that the whole of our reality is filtered through the media, including tragic events of the past. The moral and social conscience is now a phenomenon entirely governed by the media … symbolic power is always superior to the power of arms and money. … The striking thing about all present-day systems is their bloatedness: the means we have devised for handling data – communication, record keeping, storage, production and destruction – are all in a condition of 'demonic pregnancy' … So many reports, archives, documents – not a single idea generated … So many messages and signals are produced and disseminated that they can never possibly all be read. … Ours is a society founded on proliferation, on growth which continues even though it cannot be measured against any clear goals. A society whose development is uncontrollable, occurring without regard for self-definition, where the accumulation of effects goes hand in hand with the disappearance of causes … when a system rides roughshod over its own basic assumptions, supersedes its own ends, so that no remedy can be found, then we are contemplating not crisis but catastrophe. …. It is as though the two poles of our world had been brought into contact, short-circuiting in such a way that they simultaneously hyperstimulate and enervate potential energies. This is no longer a crisis, but a fatal development – a catastrophe in slow motion.*

In the central graphic (figure1:6) Vulnerable and declining populations are critically affected by abrupt changes – *kicks* – natural disasters, earthquakes, tsunamis and hurricanes and social disasters such as global and regional armed conflicts, and public health emergencies. *Kicks* are exacerbated by the impact of local and regional increase of extreme weather patterns, and become additional stressors on ecosystems and further exacerbate climate change. The increasing scale and intensity of these complexly interrelated disasters challenges our capacity to adequately respond, either in the aftermath of the events taking place or in the recovery phase of disasters.

"What we have to do," Stephen Toulmin once said to Sheldon Hackney, the University of Pennsylvania's Past President, *"is make the technical and the humanistic strands in modern thought work together more effectively than they have in the past." "Technicality, technical excellence, is no longer an end in itself. It's something which has to be kept in balance with humane consequences,"* Toulmin told Hackney. *"I'm sure that it will never be possible to get the governments of the members of the United Nations and the rest to sign a common document,"* Toulmin said. *"On the other hand, I think on the nongovernmental level there is in practice a strong and large consensus which governs the way in which people do things. And, if ethics is more a practical matter than an intellectual matter that may be what is important" . "That's what I thought you would say,"* Hackney responded, *"that it's not so much discovering the platonic ideal of justice universally, but people talking with each other across their differences and reaching some agreement".*

Nevertheless, governments must act. There are multiple social tipping points that urgently need to be addressed, including global changes in financial regulation. Immediate action must be taken to stop speculative trading in vital commodities such as oil and food which causes extreme volatility in the market. Gambling on the price of food is catastrophic for vulnerable populations, counted in the billions, for whom the rapid rise in the price of food is a matter of life or death. When food prices rise rapidly there are cascading effects, including a rise in social unrest and armed conflict, public health emergencies, a rise in the internal displacement of people, and massive migrations, all of which lead to further destruction of ecosystems, accelerating climate change, and diminishing the essential conditions for human life on the planet.

Can Science Save Us? The Great Acceleration From Adaptation to Transformation or *Annihilation*? **What Happens When Life as We Know it Ends?**

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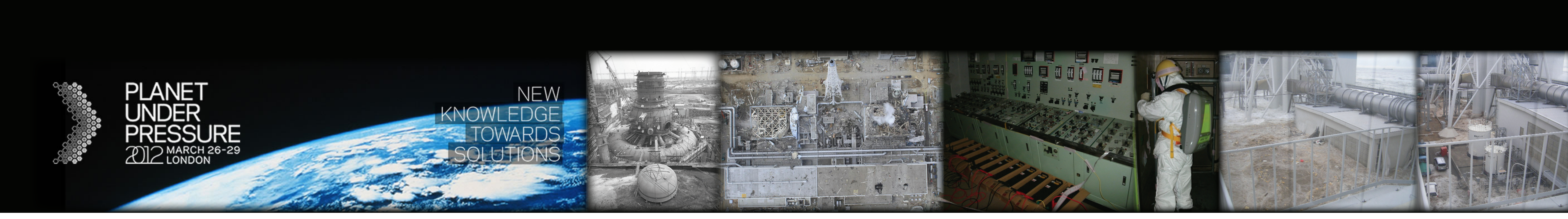

When The Temperature Rises More Than 2 ^{0}C What *Will* We Do?:

Non Linear Interrelationships Between Atmospheric And Ecosystem Stressors And Human Activity

If we cannot provide an adequate response to disasters now, what will happen when the temperature increases by more than two degrees centigrade?

When the temperature rises more than 2^0 C what *will* we do? What can we learn from our response to present catastrophes which are increasingly caused by extreme weather conditions associated with climate change? Our present emergency procedures for coping with human and ecological disasters are inadequate or non-existent. Given the ever increasing volume of disasters that people experience worldwide, we should be better prepared. *Knowing* that the temperature could rise 4^0C should galvanize us to support and participate in the planning and preparations, but it has not. Urgent action is required, but:

How can timely actions be undertaken at unprecedented and multiple geographical and geopolitical scales, where the nature and scale of the issues involved means that the actors have widely differing—and—disconnected values, ethics, emotions, spiritual beliefs, levels of trust, interests and power?

It is the enduring question, the QoQ, first asked by ICSU during the 2009-2010 Visioning that scientists are limited in their capacity to address and have no way of answering.

This poster draws on the findings of ongoing 11 year transdisciplinary study which includes emergency first response initiatives and research on social and biogeophysical disasters. The research explores "in situ" the epistemic complexity of the interconnections between: (1) climate change and extreme weather events; (2) ecological crises; (3) economic crises; (4) extreme wealth; (5) extreme poverty; (6) armed conflict; and (7) public health emergencies. The work re-examines the interconnections between the social, cultural, psychological, biological, and physical sciences, and *the humanities* – philosophy and literature –so that new questions can be asked, new understandings gained, and actions taken.

The non linear interrelationships between atmospheric and ecosystem stressors and human activity bring into sharp focus the epistemic complexity of the relationships between the physical, biological and social sciences. The potential for a step change challenges our understandings of the status quo, encourages us to rethink our positionalities within institutions, our relationships with other scientists, with the public, and with global decision makers. Any response to catastrophic events both in the present and in the future will be highly dependent on the ability of all those who participate to take into consideration the professional challenges of working with participants who hold different views of science and humanity.

"What might a 4^0C world look like?" Mark New *et al*., ask the question in "Four Degrees and Beyond", in the *Philosophical Transactions of the Royal Society A*," January, 2011. New *et al.* pose the question even though, as they point out, the 2009 Copenhagen *Accord "recognized the scientific view 'that the increase in global temperature should be below 2 degrees Celsius' despite growing views that this might be too high"*. If we cannot provide an adequate response to Real World Hazardous Events (RWHE's) at the present time, what will happen in the not too distant future? New *et. al.* write. *"Even with strong political will, the chances of shifting the global energy system fast enough to avoid 2^0C are slim. Trajectories that result in eventual temperature rises of 3^0C or 4^0C are much more likely, and the implications of these larger temperature changes require serious consideration, and the nature of the changes in climate we experience may well start shifting from incremental to transformative"*

Richard Betts *et. al.*, in the same themed edition of *Philosophical Transactions* ask *"When could global warming reach 4^0C?" They state, "While much political attention is focused on the potential for global warming of 2^0C relative to pre-industrial, the AR4* (ICPP Fourth Assessment Report) *projections clearly suggest that much greater levels of warming are possible by the end of the twenty-first century in the absence of mitigation. The centre of the range of AR4-projected warming was associated with the higher emissions scenarios and models, … including uncertainties in carbon-cycle feedbacks, and also comparing against other model projections from the IPCC, our best estimate is that the A1FI* (A1: "family of scenarios"; FI: "fossil intensive") *emissions scenario would lead to a warming of 4^0C relative to pre-industrial during the 2070s. If carbon-cycle feedbacks are stronger, which appears less likely but still credible, then 4^0C warming could be reached by the early 2060s in projections that are consistent with the IPCC 'likely range'"*. Mark Stafford Smith et al., (2011) state in the same themed edition, "Adapting to global warming of 4^0C cannot be seen as a mere extrapolation of adaptation to 2^0C," they state, "it will be a more substantial, continuous and transformative process".

The Millennium Development Goals Report (2011), refers to the 2012 UN Rio+20 *Conference on Sustainable Development, as "a major opportunity for new progress"*. But what progress will be made when the increasing scale and intensity of the complex interrelationships of RWHEs challenges the capacity of human societies to respond? The massive migrations of people and the millions of internally displaced people the Earth is currently experiencing are an indication that not only are we unprepared now, we are *un*prepared for future RWHEs.

The global erosion of social trust and the resistance of global decision makers to becoming catalysts for positive change has increased the pressure on the scientific community to "deliver knowledge", "build the capacity to deliver solutions", "effectively deliver end-to-end environmental services", "to provide new insights and solutions", "to solve real world problems", and most recently to deliver "actionable science". This begs the question: *Can science save us if scientists have outpaced the governmental capacity to respond to what's happening to the planet, or have governments outpaced science?* The paradoxical situation in which we find ourselves is that scientists can calculate planetary boundaries, but cannot "calculate" *the everyday*. Hannah Arendt writes of this as *"the curious contradictions inherent in the impotence of power"*. Curiouser and Curiouser, is that global decision makers who have a tight grip on "power" and only a rudimentary understanding of what's happening to the planet calculate the everyday as if there are only short term profits and no long term price to pay. If their present response to RWHE's and humanitarian crises is anything to go by, the impotence of their response to future disasters and potentially cataclysmic events, will , in and of itself, be a global catastrophe.

"(T)he scientific community must now deliver the knowledge that will enable countries, regions, and economic sectors to embark on transitions to sustainability in order to secure human development in the face of rapid global change," ICSU, ISSC and IGFA (the Alliance) write, *"as a means to solve real world problems. … while deepening our understanding of the Earth System and of human impacts, we must build the capacity to deliver solutions to pressing sustainability challenges at regional and global scales"*. But in real world terms what does it mean to respond as the temperature rises more than 2 degrees?

If we juxtapose a RWHE *happening now* with the Alliance proposal for Earth system Research for Global Sustainability, can we *"measure"* the effectiveness of the knowledge delivered? For instance, if we focus on *actual events* that have taken place in a country in which, against all odds, *the shift to renewable energy has occurred, that mitigates against the temperature rising, what knowledge was delivered? What actionable science* was available to provide *real world solutions* to the pressing *sustainability challenges* that the country faced?

Fukushima: Gathering Car Batteries When the Temperature Rises

The first RWHE is the Tohoku Chihou Taiheiyou Oki Mega Earthquake, which began at 14:46 on March 11, 2011. The tsunami was the second RWHE. The third RWHE was the *human induced* nuclear disaster. The Fukushima Daiichi Nuclear Power Station survived the earthquake, but the tsunami which inundated the plant resulted in: (1) a complete station black out; (2) the meltdown of the cores of three reactors; (3) the explosive destruction of three reactor buildings when the hydrogen generated by the core meltdowns ignited; and (4) major releases of radiation from the destroyed reactor buildings. If we focus on the RWHE that occurred at the Fukushima Nuclear Power Disaster, can insights be gained into some of *"the most pressing questions that the world needs answered"*, as the Alliance puts it, *"in the context of securing human development in an era of rapidly escalating global environmental risks"?* The local, national, regional and global consequences of the nuclear disaster are immediately evident, but the *inextricable complexity* of the dynamic interrelationships between the RWHE and the delivery of scientific knowledge presents a challenge.

Sabu Kohso (2011) writes, *"What has been happening in Japan since 3/11/2011 cannot be deemed merely a situation particular to a nation-state in the Far East, but unfortunately a new phase of human history, an opening toward an apocalypse, or a total transformation or both. It is a universal experience in the sense not only of its economic and environmental impact but also of the self-destruction of the apparatuses that the modern world has been building up on a planetary scale"*.

Kohso's shouts, his anguish, rooted in Hiroshima and Nagasaki, explodes on the page. Angry about the impact of the Fukushima nuclear disaster on the lives of the Japanese people, he uses the disaster as an allegory, an extended metaphor for a new phase in human history, self destructive and apocalyptic. He confronts us with the metaphoric imperative of what will happen to us on a planetary scale when the temperature rises, predicting the collapse of human societies on a planetary scale.

But in the immediacy of this moment the question that scientists must ask is whether knowledge had been delivered for actions needed to mitigate the nuclear disaster that occurred. The question can be approached from many different angles, but in this work serious consideration is given to the anomalous gathering of car batteries in an attempt to avoid a nuclear disaster. The use of car batteries challenges us to contest the rationalist assumptions about the *delivery* of scientific knowledge in the everyday world. The narratives that follow reflect a detailed analysis of three sets of documents, extracted from a much larger corpus of digitally mined data that focuses on Complete Station Blackout (CSB) conditions and the use of auxiliary power in commercial nuclear power stations both in Japan and the United States: 1)Official reports from Japan made public in the aftermath of Fukushima; 2) The Oak Ridge Nuclear Laboratory (ORNL) Browns Ferry Station Blackout Research; 3) Reports, memoranda, final draft revisions, and generic letters, supplements and corrections produced by the U.S. Nuclear Regulatory Commission (NRC).

The informational trace on auxiliary/battery power underscores the fact that scientists delivered the critical knowledge, but that it was *not effectively acted upon by policy makers in the U.S. or Japan, or by the U.S. Nuclear Regulatory Commission, or by stakeholders in the nuclear power industry.*

Official reports from Japan made public in the aftermath of Fukushima
The car battery question is grounded in an analysis of the first response account provided by TEPCO, which used plant records up to the point of the tsunami, photographs, white boards, operator logs, supervisor logs, to provide a record of what happened in the immediate aftermath of the Fukushima nuclear disaster. Excerpts from the firsthand account by Fukushima operators, the emergency response team and plant personnel follow. The underlined and bold text is in the original document.

<u>March 11, 15:42 p.m. – Activities after Loss of all AC Power.</u>
Situation at Main Control Room (MCR) of Unit 1/2
Lighting and indicators in the MCR (Main Control Room) gradually fading due to loss of all AC power. Sound of alarm was lost, too. In Unit 1-side of MCR only emergency lights remained. In Unit-2 side, all lighting was lost and it became completely dark. For IC (isolation condenser) and HPCI (high pressure coolant injection) were operable by DC (direct current, i.e. batteries) power. Operators judged HPCI was not operable because indicators on the control panel were gradually faded. For Unit 2, operating status of RCIC (Reactor Core Isolation Cooling) became unknown.

Restoration of MCR Instrumentation
The restoration team in the site emergency response headquarters prepared for necessary documents and drawings to restore power in MCRs. Also they started to gather batteries and cables at offices of contractor's office on site. The team carried batteries and cables which were collected in the site to MCR of Unit 1/2. Then confirming drawings, they started to connect the batteries to instrument panel in MCR. At the event of "ECCS (emergency core cooling system) was unavailable to inject water into the reactor", a top priority was to understand the status of water injection into the RPV (reactor pressure vessel). So restoration work was focused on connecting batteries to reactor water indicator which functions by DC power.

Batteries gathered from contractor's offices were used to supply power to the instrumentation in Unit 1 /2. Once the batteries were connected the operators were able to check the reactor water level indicators with flashlights. The tsunami took place at 15:35 and it was 21:19 for Unit 1 and 21:50 for Unit 2 when the first indications of the reactor water levels were known. Unfortunately it was too late. A Japanese Government report for Unit 1 states that TEPCO *"estimated that the fuel was uncovered about three hours* (17:46) after the earthquake with reactor damage starting one hour after that". In the immediate aftermath of the earthquake and tsunami, no one knew the state of the core, or the state of the RPV or the PCV, and so no one knew how much radiation was released into the reactor building (RB) during the first twenty four hours after the tsunami. The hydrogen generated during the core meltdown escaped both from the reactor vessel and the containment which was designed to prevent its release. The concentration of hydrogen that escaped into the huge Unit 1 reactor building was sufficient to cause the building to explode at 15:36 on March 12, twenty four hours after the tsunami. Gaseous radioactive components in the reactor escaped along with the hydrogen. All four engineered barriers to radiation release were breached or destroyed –fuel assemblies, RPV, PCV, and RB.

No one aspect of the Fukushima nuclear disaster can be fully understood without taking every other aspect of the disaster into consideration, but the use of car batteries recovered from parking lots by the emergency response team to provide auxiliary power to critical instruments in a nuclear power plant does provide an opportunity to ask *what actionable knowledge was delivered by scientists, and what happened to that knowledge once it was received?* Putting a trace on battery power makes it possible to connect past and present events and, perhaps, to mitigate disasters that might occur in the future.

ORNL Simulations of SBO Result in Core Melt at Browns Ferry

The critical knowledge that *one hour from battery loss core uncovery begins and three hours from battery loss fuel melt starts* was delivered by scientists at the Oak Ridge National Laboratory (ORNL) which was operated at that time by Union Carbide for the United States Department of Energy and the Nuclear Regulatory Commission. The research, which simulated the *Station Blackout at Browns Ferry Unit One—Accident Sequence Analysis*, was conducted by Cook, Greene, Harrington, Hodge, and Yue (1981), and is directly relevant to the Fukushima nuclear disaster. Cook *et al.* constructed a computer simulation to describe the predicted response of Unit 1 at the Browns Ferry nuclear power plant to a hypothetical SBO.

The researchers state that the computer simulation presumed "a loss of offsite power concurrent with all of the onsite diesel-generators to start and load". In the simulation *"the only remaining electrical power at the plant would be that derived from the station batteries"*, which was not the case at *Fukushima where all of the station batteries were lost.* Focusing on "Instrumentation Available Following Loss of 250 Volt DC Power" Cook et al., state, *"Reactor vessel level and pressure control can be maintained during a Station Blackout for as long as 250 DC power from the unit battery remains available"*. However, in the final phase, after the unit battery is exhausted, they write, *"a Station Blackout would constitute a Severe Accident because there would be no means of injecting water into the reactor vessel to maintain a water level over the core"*.

The ORNL SBO simulation assumed that the unit battery would last from *four to six hours.* Six accident sequences, with other equipment failures assumed to occur, were considered in which onsite AC power and DC power were not restored. *Each sequence led to core uncovery, subsequent core melting, and reactor vessel failure. Cook et al. write, "Any sequence resulting in core melt will eventually lead to containment failure if electrical power is not restored before the reactor vessel fails".*

In the companion report, *Station Blackout at Browns Ferry Unit One—Iodine and Noble Gas Distribution and Release*, Wichner, et al., (1982) write, "Battery exhaustion results in loss of the HPCI High Pressure Coolant Injection and RCIC coolant injection systems, and a boiloff of coolant begins in which the reactor vessel level decreases as the decay-heat-generated steam is vented through the steam relief valves to the pressure suppression pool. *The top of the core is uncovered one hour after the loss of battery power.* At 95 min. after the loss of battery power, the first fuel rods reach 1000°C. … The fuel rods start to fail 103 min after battery exhaustion. The failure is caused by over-temperature (1300°C) and embrittlement from the steam oxidation of the Zircaloy cladding. … The steam-zircaloy reaction quickly heats the fuel rods in the central region of the core. Two hours after the start of the boiloff, portions of the core have reached the melting point of the fuel eutectic (~2280°C) …

The core collapses 137 min after the loss of battery power. … When the core collapses into the lower plenum of the vessel, the water quenches the molten pool. The water boils away and the molten fuel heats the lower head of the reactor vessel. The heat and pressure cause the head to fail 172 min after the start of the boiloff, and the contents of the reactor vessel are dropped into the drywell sump. … The water covering the molten pool boils dry, and the fuel starts to interact with the concrete floor in the drywell. … The high temperature in the drywell causes the electrical penetration assembly seals to fail at this time. … The gases which have passed through the electrical penetrations in the drywell wall flow through the reactor building and out to the atmosphere.

These excerpts from a comparative analysis of Fukushima and the ORNL Browns Ferry SBO simulations combining the *lived experience* of a nuclear disaster with descriptions derived from theoretical science is compelling. However, if our concern is the stated purpose of the Alliance to *deliver knowledge societies need to adapt and mitigate to hazardous global environmental change,* it is the meta-analysis including the *response of decision makers* that is most critical. We know that the findings of the ORNL SBO simulations were delivered to the U.S. NRC, but what happened when *the knowledge was delivered?* How was it received? Was it *acted* upon?

October 9, 1979: Memo: The subject: TAP A-44 STATION BLACKOUT ["task action plan for unresolved generic safety issue A-44, 12/31/79"]. "I think we all agree that there may be a few plants at which station blackout poses an unacceptable risk, but that at most plants there is time for a careful and thorough study of the problem before rushing into a licensing position".. Then an informational trace is established connecting Fukushima to the decision making of the NRC. "Event sequences entailing blackout and failure to start of non-AC-dependent cooling systems will be tackled first in PWR's (pressurized water reactor), then in BWR's (boiling water reactor). *Blackout out-lasting the point of no return for the restoration of AC power will be addressed later".*

February 25, 1981: Generic Letter (GL 81-04) to all licensees of operating nuclear power reactors on "EMERGENCY PROCEDURES AND TRAINING FOR STATION BLACKOUT EVENTS".A review of current plant operations is requested "to determine your capability to mitigate a station blackout event and promptly implement, as necessary, emergency procedures and a training program for station blackout events".

June 30, 1988: NRC publishes: "Evaluation of Station Blackout Accidents at Nuclear Power Plants: Technical findings Related to Unresolved Safety Issue A-44" (NURG-1032). Critical to this chronology is the following statements, *"Perhaps the most important support system for both PWRs and BWRs is the DC power supply. During a station blackout, unless special emergency systems are provided, battery charging capability is lost. Therefore, the capability of the DC system to provide power needed for instrumentation and control can be a significant time constraint on the ability of a plant to cope with a station blackout".*

August, 1988: Seven years after the ORNL Browns Ferry SBO report, the NRC published a "Regulatory Guide to Station Blackout" *rendering actionable science inactionable.* The NRC's regulatory response to the risk of an extended SBO and a reactor meltdown was to establish an accepted range of battery power of 2 to 16 hours. The average real-life battery time for the majority of U.S. nuclear plants was *four hours* – which is coincidently, perhaps, the same number of hours that the ORNL 1981 analysis assumed for the battery life in the six SBO simulations at Browns Ferry.

February, 1990: Brookhaven National Laboratory published a report prepared for the Office of Nuclear Regularity Research – NUREG/CR-5474—entitled "Assessment of Candidate Accident Management Strategies". The report focused on prevention or mitigation of in-vessel core damage and included strategies related to the loss of power. There were seven recommendations including: conserving battery capacity by shedding non-essential loads; using portable battery chargers or other power sources to recharge station batteries; and using diesel-driven firewater pump for core injection.

On April 4, 1990, the NRC sent another Generic Letter (Generic Letter 88-20, Supplement No. 2 which was the NUREG?CR-5474 Brookhaven report) to all holders of operating licenses and construction permits for nuclear power reactor facilities. The NRC states: *"This generic letter supplement does not establish any requirements for licensees to take the specific accident management strategies into account as part of the IPE or implement any of the strategies. Adoption on the part of a licensee of any accident management strategies in response to this supplement is voluntary"*

December, 2005: The NRC published "Reevaluation of Station Blackout (SBO) risk at Nuclear Power Plants: Analysis of Loss of Offsite Power Events: 1986-2004"(NUREG/CR-6890, Vol. 1). The report provided an update on the analysis of Loss of Offsite Power (LOOP) for all 103 U.S. nuclear power plants operating at that time, based on data collected between 1986 and 2004. The NRC states: *"the loss of all ac power can be a significant contributor to the risk associated with plant operation,* contributing more than 70 percent of the overall risk at some plants" followed by "when we focus on grid-related LOOP events, the *SBO risk has increased.* Our current results show that the grid contributes 53 percent to SBO core damage frequency. *Severe and extreme weather events, which are generally related to grid events, contribute 28 percent.* Therefore, *the increasing number of grid-related LOOP events in 2003 and 2004 is a cause for concern.*

Fukushima, Browns Ferry, and the NRC: An Allegory for the Profound Meaning of What Will Happen When the Temperature Rises on a Planetary Scale

July 12, 2011: The NRC published "Recommendations for Enhancing Reactor Safety in the 21st Century: The Near Term Task force Review of Insights from the Fukushima Dai-ichi Accident." Tier 1 - NTTF Recommendation 4.1. *The Task Force recommends that the NRC strengthen station blackout (SBO) mitigation capability at all operating and new reactors for design-basis and beyond-design-basis external events. 4.1 Initiate rulemaking to revise 10 CFR 50.63 to require each operating and new reactor licensee to: (1) establish a minimum coping time of 8 hours for a loss of all alternating current (ac) power, (2) establish the equipment, procedures, and training necessary to implement an "extended loss of all ac" coping time of 72 hours for core and spent fuel pool cooling and for reactor coolant system and primary containment integrity as needed, and (3) preplan and prestage offsite resources to support uninterrupted core and spent fuel pool cooling, and reactor coolant system and containment integrity as needed, including the ability to deliver the equipment to the site in the time period allowed for extended coping, under conditions involving significant degradation of offsite transportation infrastructure associated with significant natural disasters.*

August 19, 2011, NRC published the Commission Voting Record in response to the *Near-Term Report and recommendations for Agency Actions Following the Events in Japan* (SECY-11-0093). In commenting on the NTTF, Chairman Jaczko noted, *"Recommendation 4 provides for improving mitigation of station blackout events (SBO) where a nuclear plant loses all AC power. While many of the contributing causes to the conditions learning to core damage at Fukushima Dai-ichi remain unknown at this time, operating strategies and equipment did not provide sufficient operating margin to prevent core damage for the low-probability events involving extended loss of AC power. There is no doubt that the cross-cutting aspect of the prolonged loss of electrical power at Fukushima Dai-ichi severely impacted the ability of the site's operators to prevent and to mitigate the accident. The Task Force recommended that the Commission direct the staff to begin the actions to further enhance the ability of nuclear power plants to deal with the effects of prolonged SBO conditions at single and multiple unit sites without damage to the nuclear fuel in the reactor or spent fuel pool, and without the loss of reactor coolant system or primary containment integrity. …*

October 3, 2011: Letter: SUBJECT: PRIORITIZATION OF RECOMMENDED ACTIONS TO BE TAKEN IN RESPONSE TO FUKUSHIMA LESSONS LEARNED (SECY-11-0137). The NRC staff assessment is included as an enclosure: The specific July 12 NTTF recommendation 4.1 to replace the August 1988 "4 hour battery rule" and issue a new "8-72-extended coping as needed rule" is not in the Staff Assessment. The NRC staff concludes that: *This regulatory action would consider the need for SBO power source(s) and mitigating equipment to be diverse and protected from external events. This regulatory action would also examine whether there is a need to expand SBO mitigation requirements to require power reactors to mitigate an SBO event at a plant (each unit for multiunit site) until either the onsite or offsite power source is restored to bring the power reactor to a cold shutdown and to maintain spent fuel pool cooling.* The staff said the schedule for developing the new rule was 4.25 years.

October 11, 2011: The National Resources Defense Council (NRDC) expressed agreement with the NTTF recommendations and stated that the 4.25 year timetable for issuance of a final rule "is far too leisurely".

January 2012, the NRC published a brightly colored reassuring brochure described as "a plain language summary" for the public on the safety of nuclear power. *Modeling Potential Reactor Accident Consequences* is filled with reassurances. In the "Key Results" descriptors include "operators were successful", "they can prevent the reactor from melting", "accidents progress more slowly and release much smaller amounts of radioactive material than calculated in earlier studies", "the public health consequences are smaller", "reduce the risk of public health consequences", "no risk of death during or shortly after the accident", "longer term cancer fatality risks … are millions of times lower than the general U.S. cancer fatality risk". Thus irrefutable evidence is obfuscated by key decision makers in a textural maneuver that covers up dangerous scenarios and maintains the present status and protects the profits of the nuclear power industry.

Just five months (August 9, 2011) before *Modeling Potential Reactor Accident Consequences* was published, the Chairman of the NRC wrote: *Almost immediately after receiving the Task Force report, the Commission began discussions of the process to review the report, and not, unfortunately, on the content of the report and its profound meaning for nuclear safety. Several of my colleagues have found one aspect of the report they accept without question. The most frequently cited statement is that "continued operation and continued licensing activities do not pose an imminent risk to public health and safety." A majority of the Commission appears to accept this statement without the need for further scrutiny, debate, or discussion. On the other hand, the substantial body of the Task I Force report which details safety gaps in our regulatory system, and all of the recommendations about how to close those gaps do require additional analysis, according to my Commission colleagues.* The same "nuclear power is safe message" is also being given to the stakeholders and the public.

January 13, 2012, The NRC published a status update on the NTTF recommendations in which they state the staff has "reconsidered it's proposed approach" citing House and Senate Hearings, and letters from the Advisory Committee on Reactor Safeguards (ACRS). As it stands at the time of writing (March, 2012) the Commission has directed the SBO rulemaking be completed within 24-30 months.

It is more than 30 years since the ORNL Browns Ferry SBO research findings were published showing that after one hour the top of the core is uncovered, and that within two hours the core starts to melt. If we measured the effectiveness of the knowledge delivered? Fukushima delivered the knowledge. It took a cataclysmic nuclear accident to uncover the documentation produced by the NRC which reveals that the official discourse of decision makers is highly *persuasive* and extremely effective at *obfuscating scientific knowledge.* Which brings us back to Kohso's allegorical interpretation of the Fukushima disaster and the metaphoric imperative for scientists, the public, and those who hold power to rethink and reimagine what will happen on a planetary scale when the temperature rises and human societies are left high and dry or lost beneath the sea.

Can Science Save Us? The Great Acceleration From Adaptation to Transformation or *Annihilation*? **What Happens When Life as We Know it Ends?**

Denny Taylor, International Center for Everybody's Child, Hofstra University