FLAT EARTH—SCARED

ROUND EARTH—AGGRESSIVE

COMPLEX EARTH--?????????

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prepared for a Keynote Talk at the

WORKSHOP ON EARTH SYSTEMS ENGINEERING
Toward Developing Sustainable Engineering Solutions
in a Complex Natural World

University of Colorado
Engineering Center, Boulder, Colorado
October 4-6, 2001
Aristotle--Nature, for Aristotle, is an organic system of things whose common forms make it possible to arrange them into classes comprising species and genera, each species having a form, purpose, and mode of development in terms of which it can be defined. The aim of theoretical science is to define the essential forms, purposes, and modes of development of all species and to arrange them in their natural order in accordance with their complexities of form, the main levels being the inanimate, the vegetative, the animal, and the rational. The soul, for Aristotle, is the form, or actuality, of the body, and humans, whose rational soul is a higher form than the souls of other terrestrial species, are the highest species of perishable things. The heavenly bodies, composed of an imperishable substance, or ether, and moved eternally in perfect circular motion by God, are still higher in the order of nature. This hierarchical classification of nature was adopted by many Christian, Jewish, and Muslim theologians in the Middle Ages as a view of nature consistent with their religious beliefs.

Aquinas--The truths of natural science and philosophy are discovered by reasoning from facts of experience, whereas the tenets of revealed religion, the doctrine of the Trinity, the creation of the world, and other articles of Christian dogma are beyond rational comprehension, although not inconsistent with reason, and must be accepted on faith. The metaphysics, theory of knowledge, ethics, and politics of Aquinas were derived mainly from Aristotle, but he added the Augustinian virtues of faith, hope, and charity and the goal of eternal salvation through grace to Aristotle's naturalistic ethics with its goal of worldly happiness.

Modern Philosophy

Since the 15th century modern philosophy has been marked by a continuing interaction between systems of thought based on a mechanistic, materialistic interpretation of the universe and those founded on a belief in human thought as the only ultimate reality. This interaction has reflected the increasing effect of scientific discovery and political change on philosophical speculation.

Mechanism and Materialism

… The medieval view of the world as a hierarchical order of beings created and governed by God was supplanted by the mechanistic picture of the world as a vast machine, the parts of which move in accordance with strict physical laws, without purpose or will. … In this new philosophical view, experience and reason became the sole standards of truth.

Francis Bacon--called for a new scientific method based on inductive generalization from careful observation and experiment. He was the first to formulate rules of inductive inference. (Author’s note: I will add a reference here later which infers that Bacon believed that we should “rape and pillage the earth—make “her” bend to our rule.”)

Galileo-- Galileo brought attention to the importance of applying mathematics to the formulation of scientific laws. This he accomplished by creating the science of mechanics, which applied the principles of geometry to the motions of bodies. The success of mechanics in discovering reliable and useful laws of nature suggested to Galileo and to later scientists that all nature is designed in accordance with mechanical laws. (Authors note: this can be interpreted to mean that we use measurable quantities (no qualities are considered in science)).

Descartes--made mathematics the model for all science, applying its deductive and analytical methods to all fields. … maintained that mind and body are two distinct substances, thus exempting mind from the mechanistic laws of nature and providing for freedom of the will. His fundamental separation of mind and body, known as dualism, raised the problem of explaining the way in which two such different substances as mind and body can affect each other, a problem that he was unable to solve and that has been a concern of philosophy ever since.

See http://beta.encarta.msn.com/find/Concise.asp?z=1&pg=2&ti=761574677
The New Physics—Quantum Mechanics and Relativity

“The conception of the universe as an interconnected web of relations is one of the two major themes that recur throughout modern physics. The other theme is the realization that the cosmic web is intrinsically dynamic. The dynamic aspect of matter arises in quantum theory as a consequence of the wave nature of subatomic particles, and is even more central in relativity theory, which has shown us that the being of matter cannot be separated from its activity. The properties of its basic patterns, the subatomic particles, can be understood only in a dynamic context, in terms of movement, interaction, and transformation.” (Reference: Capra, Fritjof, *The Turning Point*, Simon and Shuster, New York, 1982, p. 87).

Evolution


The Living Earth

“Life is planetary exuberance, a solar phenomenon. It is the astronomically local transmutation of Earth’s air water and sun into cells. It is an intricate pattern of growth and death, dispatch and retrenchment, transformation and decay. Life is the single expanding organization connected through Darwinian time to the first bacteria and through Vernadskian space* to all citizens of the biosphere. Life as God and music and carbon and energy is a whirling nexus of growing, fusing, and dying beings. It is matter gone wild, capable of choosing its own directions in order to indefinitely forestall the inevitable moment of thermodynamic equilibrium—death. Life is also a question the universe poses to itself in the form of a human being. (Reference: Margulis, Lynn, and Dorion Sagan, *What is Life?* Simon and Shuster, New York 1995, p.49). (*Vernadsky showed that all life inhabited a materially unified place, the biosphere. Reference: Ibid, p. 47).
“Expanding the Institutions of Science”

Bruce Alberts  
President  
National Academy of Sciences

138th Annual Meeting  
Washington, D.C.  
April 30, 2001

See [http://www.nationalacademies.org/president/alberts.html](http://www.nationalacademies.org/president/alberts.html)

“Changing the nature of science education”

Our Academy has a very special role in defining and promoting good science education. Our major report, the National Science Education Standards, has given the nation a roadmap for a revolutionary change in the nature and extent of science teaching in our schools. Our partnership with the American Association for the Advancement of Science (AAAS) in this endeavor has helped to create a strong consensus movement, focused on providing a new type of science education for all Americans.

The Standards call for science to be taught to all students in the form of "science as inquiry." In this form of science teaching, students are encouraged to struggle with a problem and to discuss it with their classmates before being told the answer. The emphasis is on using evidence to make logical arguments, which requires the development of both analytical and communication skills. The aim is not to "cover the material," but to empower students with the abilities they will need to be able to learn on their own. These are not simply the skills that one needs to become a scientist or engineer. In our complex society, these are skills that everyone needs in order to become an effective citizen -- and/or a productive employee in today's ever-changing world of work.

In this view, science education becomes a centerpiece in everyone's education, fully equal in importance to reading, writing, and mathematics.”
“Several things have changed to create these new macro ethical questions in engineering, but I am going to focus on one: complexity. Moreover, I will focus specifically on complexity arising from the use of information technology and biotechnology in an increasing number of products. The key point is that we are increasingly building engineered systems that, because of their inherent complexity, have the potential for behaviors that are impossible to predict in advance.

Let me stress what I just said. It isn't just hard to predict the behavior of these systems, it isn't just a matter of taking more into account or thinking more deeply—it is impossible to predict all of their behaviors.

…

Over the last several decades a mathematical theory of complex systems has been developing. It's still immature compared to the highly honed mathematical tools that are the heart of modern engineering, but one thing is very solid—a sufficiently complex system will exhibit properties that are impossible to predict a priori!

…

So, that's what has changed. We can, and do, build systems not all of whose behaviors we can predict. We do, however, know that there will be some such unpredicted behaviors— we just don't know what they will be. The question then is: How do we ethically engineer when we know this—when we know that systems will have behaviors, some with negative or even catastrophic consequences—but we just don't know what those behaviors will be?”
“Developing the capability to engineer at the level of global systems -- from energy, transportation, and information systems to the carbon and nitrogen cycles -- is the next great challenge for engineering. This "Earth systems engineering" (ESE) capability will not replace traditional engineering disciplines, but will augment them. However, to address the complexities and dynamics of global systems, it will require a fundamentally different way of engineering (Allenby, 1999a).

We must begin by recognizing a basic, if disconcerting, truth: the Earth, as it now exists, is a human artifact. It reflects the (frequently unintended and unconscious, but nonetheless real) design of a single species. Although this process has been accelerated by the industrial revolution, "natural" and human systems at all scales have in fact been impacting each other and co-evolving together for millennia, and they are now more tightly coupled than ever.”

…

Note: Allenby discusses the principles of earth systems engineering in this article. Twelve “obvious ESE principles” are presented and discussed.
Complex Earth--???

Let’s treat this as a complex problem and attempt to transform the patterns that we observe into language (see Weiss, Paul, Hierarchically Organized Systems in Theory and Practice, Hafner Publishing Company, New York, 1971, p. 1) that can be used to vision the emergence of complex engineering education for the future that starts now. Like Weiss, we note that the language for something different than the norm does not come easily, so we must be patient and be willing to learn. The attributes of our vision should apply to this struggle and journey that we are about to undertake.

As we start this journey, we can prepare ourselves for what lies ahead by the following analogy. Right now, we treat engineering education like “kicking a rock.” If we are also going to embrace the complexity that the biosphere brings, then, in addition, we must treat engineering education like “kicking a dog.”

So here we go…..

We should consider the world as simple and complex, and complex and simple. Our students should learn about simple systems. They should study the classics from the Cartesian Era with enough rigor that they are not scared to go there. Our students and professors, the “Academy”, must embrace complexity. We engineer in our biosphere. We design, build and create systems that are nested in and interact with the biosphere. We must in our fundamental engineering education (and in our continuing education) understand and utilize reductionism and holism, analysis and synthesis, and information and knowledge. Bill Best, President and CEO of Thermal Engineering Corporation (one product is auto paint drying systems—Saturn uses his) gives a necessary and sufficient interpretation to simple and complex. Simple analysis methods should be exhausted (necessary) and coupled with complex methods (sufficient) when designing and building engineered systems.

Place and time must become two of the most important foundational underpinnings of our engineering educational philosophy. Place and time are ubiquitous concepts and realities in our biosphere home. We must learn where we (the biosphere) came from and the places we visited in our journey to get here. We must learn about the time scale of this journey. Our engineered systems are designed and built for a place and function and exist in the future. Engineers must have a good grasp of time and space in order to create human artifacts and living systems that are in harmony and coherent with the time and space scales of the biosphere. (For some enjoyable reading on this and other pertinent topics see the writings of Daniel Quinn--Ishmael, Providence, Story of B, and My Ishmael. See also the writings of Thomas Berry—Dream of the Earth and The Great
Work: Our Way into the Future. In particular, see Chapter 7 in The Great Work; in this chapter, Berry says, “It is time for the universities to rethink themselves and what they are doing.”

William Wulf challenged us to start the dialog on a macro ethic, especially in light of the complexity of the engineering problems we face. We must start this journey and it should be integrated into all that we struggle to teach our students (and learn from them). We should view ethics as a nested complex problem: individual/practice ethics nested within institutional ethics nested within a global macro ethic for our biosphere home. Maybe we could take some hints from and work with our philosopher colleagues on this challenge. We could look to the land ethic of Aldo Leopold: “A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise.” (Reference: Leopold, Aldo, A Sand County Almanac, Oxford University Press, New York, 1949, p. 263). Callicott added climatic and ecological dynamics to Leopold’s land ethic when he modified it to read, “A thing is right when it tends to disturb the biotic community only at normal spatial and temporal scales. It is wrong when it tends otherwise.” (Reference: Callicott, J. Baird, Beyond the Land Ethic, State University of New York Press, Albany, NY, 1999, p. 138). Let the journey begin.

We must utilize Bloom’s Taxonomy (knowledge, comprehension, application, analysis, synthesis, evaluation) in our engineering teaching/learning and practice processes. (Reference: Bloom, B.S. (Ed.) (1956) Taxonomy of educational objectives: The classification of educational goals: Handbook I, cognitive domain. New York ; Toronto: Longmans, Green.). We must adapt Bloom’s Taxonomy to include complex systems thinking so that we design and build systems that are “right” for the biosphere. The process of pattern identification, recognition and evaluation is an example of such an adaptation.

We’ve really got to do this one and quit giving it lip service. Our engineers must learn how to work on multi-disciplinary teams and how to analyze, synthesize and evaluate complex information that is flowing between and among team members and around and through the team. Engineering and non-engineering language, information and communication become very important. Engineering and non-engineering experiences become very important. Engineering becomes a form of active, adaptive and symbiotic system design, build and management (monitor and adjust). Harold Geneen gave us the “cooking on a wood stove” analogy in his book on managing (Reference: Geneen, Harold, and Moscow, Alvin, Managing, Doubleday, New York, 1984, p. 29). The same analogy applies to engineering in and on a complex biosphere.
The concept of health becomes an important concept that we can draw on if we accept the challenge of preparing students to engineer systems for the living complex biosphere. We have a lot to learn from the process of teaching/learning that takes place as a medical doctor is trained and educated. Health, good or bad is something that we experience everyday as we proceed along the timeline of birth, living and death. We should bring this valuable indigenous knowledge into our life work.

We must abandon the culture that evolved from the popular slogan “Just Do It.” I agree that by our nature we are inclined to “do it” whatever “it” is. But we should make sure that our students learn something more akin to the Shewhart cycle, plan-do-check-act-plan-do-check-act-plan-etc. (Reference: Mitra, Amitava, *Fundamental of Quality Control and Improvement*, McMillan, New York, 1993, p. 44). The new and improved cycle needs to incorporate simple and complex methods and measures with an appropriate space and time scale. Our students must be encouraged to be analytic and intuitive modelers and evaluators. They must not be hesitant to observe and evaluate (critique) emergent patterns of system behavior. If we do a good job, they will have the educational background and a macro ethic to support them.

Let me end with a quote from an invitation to do research as a NASA University Research, Engineering and Technology Institutes (URETIS). This is how it reads: “Institute Focus: The union of biotechnology with nanotechnology is a natural one. The emphasis in nanotechnology is to work with molecular organization of matter that leads to useful macrostructures. Nature builds systems of staggering complexity, yet these systems provide robust, autonomous, and efficient solutions, which are well adapted to the environment. Eyes of the living systems can almost respond to a single photon. Fireflies convert chemical energy to light with high efficiency. Birds can make complex flight maneuvers instantaneously. Skin heals by itself after injury. Biological systems offer fresh inspiration for engineering solutions.

Some unique characteristics anticipated from materials and structures research in bio/nanotechnology include multifunctionality, hierarchical organization, adaptability, self healing/self-repair, and durability. It is also promising to develop hybrid systems by combining biologically engineered components to non-biological systems. The ability to create materials and structures by placing atoms or molecules at predesigned locations provides a unique opportunity to produce building blocks without the need to machine materials. This will allow tailoring of the mechanical properties to meet the design requirements and revolutionize aerospace vehicles (aircraft and spacecraft).
Clearly, bio-nanotechnology efforts have to be multidisciplinary. This can be achieved within key research universities with an effective cross-disciplinary skill mix and infrastructure.

Although activities at the URETI should be focused towards enabling developments in the aerospace arena, creativity and innovation at the participating institutions should not be constrained. The need to understand materials and structures at the nanoscale for the sake of building biologically inspired, multifunctional macroscale structures and devices requires there be synergistic efforts in theoretical and experimental activities such as materials synthesis, characterization, modeling, and simulation. Efforts should be made to bridge length and time scales ranging from the atomistic through the meso to the macro scale. (Reference: [http://www.eps.gov/spg/NASA/HQ/OPHQDC/CAN-01-OAT-01/Attachments.html](http://www.eps.gov/spg/NASA/HQ/OPHQDC/CAN-01-OAT-01/Attachments.html)).

**Folks, we have arrived at and on the complex biosphere—what’s next?**