Tragedy in the Gulf

A Call for a New Engineering Ethic

Tragedy in the Gulf: A Call for a New Engineering Ethic
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Synthesis Lectures on Engineers, Technology, and Society

Editor
Caroline Baillie, ***University of Western Australia***

The mission of this lecture series is to foster an understanding for engineers and scientists on the inclusive nature of their profession. The creation and proliferation of technologies needs to be inclusive as it has effects on all of humankind, regardless of national boundaries, socio-economic status, gender, race and ethnicity, or creed. The lectures will combine expertise in sociology, political economics, philosophy of science, history, engineering, engineering education, participatory research, development studies, sustainability, psychotherapy, policy studies, and epistemology. The lectures will be relevant to all engineers practicing in all parts of the world. Although written for practicing engineers and human resource trainers, it is expected that engineering, science and social science faculty in universities will find these publications an invaluable resource for students in the classroom and for further research. The goal of the series is to provide a platform for the publication of important and sometimes controversial lectures which will encourage discussion, reflection and further understanding.

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State University of New York at Binghamton

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ABSTRACT

The recent tragedy in the Gulf of Mexico and resultant ethical consequences for the engineering profession are introduced and discussed. The need for a new engineering ethic is identified and introduced based upon advancements in science, complex systems and eco-philosophy. Motivations for introducing a new ethic rather than modifying existing ethics are also discussed.

KEYWORDS

engineering ethics, quantum mechanics, complex systems, eco-philosophy, oil spill

May all beings be free of suffering.
May all beings' voices be heard.

For Yukon, Nikki, and Snickers
For Francesca and Lupi

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Preface

> *"We cannot simply think of our survival; each new generation is responsible to ensure the survival of the seventh generation. The prophecy given to us, tells us that what we do today will affect the seventh generation and because of this we must bear in mind our responsibility to them today and always."*
>
> *Audrey Shenandoah, Onondaga Nation*[1]

The tragedy of the oil spill in the Gulf of Mexico in 2010 has served as the catalyst for my re-examination of the ethics of the engineering profession. Through the course of writing this book I discovered that the incident at the Deepwater Horizon rig rather than being an isolated and extremely rare occurrence is repeated time and time again throughout the world. Many different disciplines in engineering play an important role in the exploration, drilling, removal and transport of oil as is true in nearly all the technologies we use and often take for granted in our modern world. So while the oil spill triggered this re-examination, the issue of ethical responsibility in engineering is much greater than just this one industry.

Engineering is a profession with an ethical dimension and has help propel technical advancements across the planet. Technology, science and engineering are advancing at incredible rates. With these mind-boggling advances, it is now an appropriate time to ask the following question: Has our understanding of our ethical responsibilities both as a profession and as individual practitioners kept pace with those advancements? I suggest that it has not, and as a result, offer a new engineering ethic.

The new ethic will integrate understandings of the workings of the Universe from such disparate fields as quantum mechanics and eco-philosophy. Ideas from the emerging science of complex systems will be incorporated as well. From quantum mechanics we shall use the notions of potentialities, uncertainty, connectedness and the importance of experience. From eco-philosophy, we shall utilize the idea of the evolving, dynamic nature of the Universe and the important laws of differentiation, communion and subjectivity. Lastly from complex system science, we shall incorporate the concept of non-linearity, self-organization and emergence.

I offer this ethic now because I want to ask all of us in engineering to reflect upon our understanding of our ethical responsibilities as a profession. Whether or not anyone finds my arguments compelling does not matter in the final analysis. That which does matter is whether or not we as a profession are doing all that we can to safeguard our beautiful planet and all its inhabitants for our collective future.

At a recent presentation, the architect William McDonough[2] noted that many of the members of the audience were, in fact, the seventh generation measured from the time of Thomas Jefferson. Imagine. We now are Thomas Jefferson's seventh generation. After reflecting upon how much technology has advanced and how much greater the impact that it has on our modern lives, I could not help but think to the future and contemplate that advancement and associated impact seven generations from today. While that world is certainly beyond our vision it is not entirely outside of our control. The decisions we make as a profession particularly with respect to our ethical responsibilities will have a profound impact on the world our seventh generation inherits.

George D. Catalano
December 2010

CHAPTER 1

Tragedy in the Gulf

1.1 SUMMARY

The recent tragedy in the Gulf of Mexico and resultant ethical consequences for the engineering profession are introduced and discussed. The need for a new engineering ethic is identified and introduced based upon advancements in science, complex systems and eco-philosophy. Motivations for introducing a new ethic rather than modifying existing ethics are also discussed.

1.2 INTRODUCTION

Ethical concerns are too often addressed after a tragic accident. This certainly was true of the case for deepwater drilling in the Gulf in 2010 as well as for countless other oil spills as documented throughout the world over the course of the last century. It was only after we were confronted with graphic photographic imagery of countless oil soaked birds and marine life, and heard testimonies of Gulf coast residents whose very culture was gravely threatened that we focused our attention as a society on the disaster. As a profession, we seem even more reluctant to tackle the ethical issues involved. Given the rate that new technologies are emerging and converging, and the damage that accidents such as the Deepwater Horizon oil spill have done to the integrity and reputation of our profession, it seems that what we need a new comprehensive ethical approach, one that will be able to deal with not only the technical issues involved but equally as well with the environmental and societal implications. The present work offers such an approach.

On April 20, 2010, a series of explosions ripped through a giant oil-drilling rig, the Deepwater Horizon, located in the Gulf of Mexico, forty-eight miles from shore. One hundred and fourteen workers survived the blast while eleven others would never be found. After two days burning at sea, the rig collapsed and sunk, tearing steel piping and opening what was referred to at the time as an "oil volcano" that sent approximately two hundred million gallons of crude oil into the Gulf over the course of the summer. Coastal waters, deep-ocean, estuaries, wetlands and beaches were devastated by the crude oil spillage. Wildlife and wildlife habitat from Texas to the Florida Keys were grievously threatened. Countless individuals and families who depend upon the Gulf waters for their jobs and their very way of life were economically and emotionally devastated.

The Deepwater Horizon oil spill disaster has put the following questions before our profession:

What exactly happened?

What role did the engineering profession play in contributing to the disaster?

How do we prevent such tragic accidents in the future?

What are our ethical responsibilities in events such as the Deepwater Horizon spill?

Are the codes of conduct that we have developed in engineering adequate?

Let us look to new ideas as we wrestle with the tragedy and attempt to construct an engineering ethic that might help prevent such tragedies in the future. Also, let us turn to developments in several technical areas – complex systems science and quantum mechanics as well as new ideas in our understanding of the unfolding nature of our universe. From complex systems science, we will learn about not only complexity but also about emergence, self-organization and uncertainty. From quantum mechanics, we will explore the connectedness of the Universe. Finally, our new understanding of the Universe suggests that it is governed by three fundamental laws, the laws of differentiation, subjectivity and community, all of which we shall consider carefully.

The *Engineering New Record (ENR)* is one of the premier construction industry web site featuring headline news, searchable directories of engineers, contractors and industry job listings for architects, engineers, designers, real estate developers, builders and contractors. *ENR* is part of McGraw-Hill's Construction Information Group, together with other brands including *FWDodge, Sweet's* and *Architectural Record*. The publication seems far removed from political discourse and from promoting any specific agenda.

On June 2, 2010, *Engineering New Record*[3] published an editorial, which focused upon the Gulf oil spill disaster as well as the responsibility and culpability of the engineering profession for the tragedy. The editorial was provocatively entitled, "The Gulf Oil Spill Disaster Is Engineering Shame."[4] Starting with a poignant reminder of the basis for all engineering ethics codes – the obligation to the greater good of society – the article then notes that "the profession prides itself on civic virtue and requires individuals to have a functioning conscience" and wonders when the profession's professional societies will speak out. The absence of such voices has been in their view, quite stunning.

At a recent annual conference of engineering educators held several months after the original explosion whose participants hail from the nation's finest engineering programs and whose ranks include from among the nation's very best engineering faculty, the tragedy in the Gulf was notably absent from keynote addresses, panel discussions and presentations though it dominated the news at the time. Several of us in attendance were left to wonder why – why did we not feel the need to speak out, to express outrage or to focus our attention on the fact that "we've punctured the seabed a mile down but can't stop the hemorrhaging."

The *ENR* editorial continues:

> "The U.S. hasn't reconciled the idea that engineers can render miracles—cloud-piercing towers, low-cost instantaneous digital communication, deep-sea drilling—with the idea that each fresh miracle hurls us into unfamiliar territory. The key issue isn't that the Gulf oil spill has violated expectations of a quick technological fix; it's that engineering by its nature produces new risks.

> If engineers help each other protect against corporate power and technological overreaching, the profession may reclaim lost esteem. Otherwise, the Gulf of Mexico always will be remembered as the place where engineering prestige dipped to a new low in an age known for disasters as much as for progress."

There was an immediate outpouring of letters to the editor of *Engineering New Record* with feedback ranging from accusations that *ENR* had been taken over by a cabal of leftists to grudging support for the need to embrace the lessons learned from the tragedy and move the profession towards a more encompassing engineering ethic. The question that the present work addresses is how might we do that in our profession – make it more encompassing – and do it in a way which the practitioners might be receptive to such new ideas? Put another way, how might we develop a new engineering ethic, which focuses more upon the results as evidence by its adoption across the myriad of disciplines rather than the purity or elegance of the argument?

1.3 A NEW ETHIC – WHERE MIGHT WE LOOK?

Developments in complex systems science and quantum mechanics serve as the beginning of our journey towards the development of a new ethic. Buttressed with these new ideas, we will turn our attention the work of Berry[5] and Swimme and Berry[6] who describes the Universe in holistic terms and whose development or unfolding is governed by fundamental principles.

There are exciting new developments in what is referred to as complex system science, one of the fastest growing areas of science. The science of complex systems governs the world around us. New computer modeling approaches are revealing the common features of systems as diverse as the weather, economies and ecosystems, and they are improving our understanding of the unexpected emergent behavior that these complex systems exhibit.

What is a complex system? Genomes, ecosystems, stock markets, the weather and society are all examples of complex systems – large aggregations of many smaller interacting parts. These parts may be species, investors, air particles or individuals. Two properties set a complex system apart from one that is merely complicated are emergence and self-organization. Emergence is the appearance of behavior that could not be anticipated from knowledge of the parts of the system alone. Cyclones, tornadoes or weather systems are emergent features of the motion of air particles on the spinning Earth. Financial recessions and booms are emergent features of national economies. Complicated artifacts like cars or power plants also have emergent features in this sense, so a further property is needed to distinguish complex systems. This is self-organization. This means that there is no external controller or planner engineering the appearance of these emergent features. They appear spontaneously.

Recently, it has been observed that there are general laws and rules governing these processes, which apply equally to the weather, to society and to life itself. A key feature of real systems that has proved to be essential in the appearance of rich emergent features is local interaction. In other words, elements of a system only interact with their neighbors. These interactions can be represented by simple rules that describe how the state of any element in the system is dependent on the state of its neighbors. For example, transmission of a disease usually depends on contact between individuals. Simple models of epidemics that assume a ’well-mixed’ population often fail to predict the rate of spread and resistance to eradication of many diseases.

Scientists are now developing computer models of complex systems based on local interaction rules. In the social domain, the resulting computer models are reshaping our understanding of social and economic processes, including phenomena like societal resilience and collapse.

Another place we may look for the foundations of a new engineering ethic might be found in quantum mechanics. According to the ***Stanford Encyclopedia of Philosophy***,[7] “Quantum mechanics is, at least at first glance and at least in part, a mathematical machine for predicting the behaviors of microscopic particles — or, at least, of the measuring instruments we use to explore those behaviors — and in that capacity, it is spectacularly successful: in terms of power and precision, head and shoulders above any theory we have ever had.”

In the present work, we are not interested per say in the mathematical details but rather what kind of world does the science of quantum mechanics describe. This question, however, is extremely controversial; “there is very little agreement, among physicists and among philosophers, about what the world *is like* according to quantum mechanics.”[8] Accordingly, we shall limit are consideration of the implications of quantum mechanics to two principles: rather than a Universe described as being deterministic, in a quantum world the Universe can best be described as a rich tapestry of potentialities; and rather than a collection of disparate objects, the Universe is more accurately described as one, connected system.

Berry[9] offers us the following contemplation: what would our ethical responsibilities be if we considered the Universe as a “communion of subjects” rather than a “collection of objects.” Martin, Swimme, et al.[10] suggest a Universe whose unfolding is governed by a set of immutable principles, chief among them being differentiation, subjectivity and communion. At first glance, these ideas from particularly Berry[1] and Swimme[2] seem the esoteric ramblings of eco-theologians that have little to do with the practice of engineering. I would suggest the opposite is true, that the ideas embedded in the notion of a Universe as a communion of subjects rather than being far removed from the practice of our profession are deeply grounded in the developments in the sciences from which we base our understanding of world in which we live.

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[1] Fr. Thomas Berry, C.P. was a Catholic priest of the Passionist order, cultural historian and eco-theologian. Among advocates of deep ecology and “ecospirituality,” he is famous for proposing that a deep understanding of the history and functioning of the evolving universe is a necessary inspiration and guide for our own effective functioning as individuals and as a species. He is considered a leader in the tradition of Teilhard de Chardin.

[2] Dr. Brian Swimme is a professor of cosmology at the California Institute of Integral Studies in San Francisco. Brian Swimme’s primary field of research is the nature of the evolutionary dynamics of the Universe. Swimme brings a new interpretation of the human as an emergent being within the Universe and Earth. His central concern is the role of the human within the Earth community. Toward this goal, in 1989, Swimme founded the Center for the Story of the Universe, a production and distribution affiliate of the California Institute of Integral Studies.

1.4 A NEW ETHIC – WHY?

Engineering is awash with codes of ethics. A logical question one might ask is why another engineering ethic? What possible argument can be made for a more responsible profession than has already been set forth? Perhaps even more importantly, why should anyone listen? In fact, it is my view that this is the most important element of all – to offer a new ethical paradigm that calls for a broadening of our sense of responsibilities to the environment and to the rest of the planet, one which might actually be considered seriously for adoption.

The present work seeks to offer one approach that might work, borrowing from our developing view of complex systems theory, our understanding of the possible implications of quantum mechanics and our reflections upon the dynamic nature of the Universe. As one example of an important characteristic of a complex system – and we shall consider others – is that a system is composed of interconnected parts that as a whole exhibit one or more unexpected properties. Stated another way, the behavior among the possible properties may not be obvious from the properties of the individual parts. This characteristic of every system is called emergence and is true of any system, not just complex ones. Examples of complex systems include ant colonies, human economies and social structures, climate, nervous systems, cells and living things, including human beings, as well as modern energy or telecommunication infrastructures.

Whether or not this attempt at developing an engineering ethic that might help prevent tragedies such as the one in the Gulf is beyond this author's control. I am reminded of an answer Fr. Daniel Berrigan, the former chaplain at Cornell University gave to a questioner at the site of the university's homecoming ceremony in 2007. A Cornell alumnus asked, "With perhaps even more violence and social injustice in the world today then was known in the 1960s, do you feel that your lifelong commitment to action in the face of such violence and injustice has been a life led in vain?" Fr. Berrigan responded: "I have tried to act in ways which I felt to be right. Whether or not I made a difference really or what the long term consequences might be was not part of my consideration." Berrigan went on to say, "I believe it is the right thing to do."[3] The present effort is offered in that spirit. I believe that engineering needs a new ethic – one that might help in preventing Deepwater Horizon tragedies in the future. The present work is my attempt to follow Father Berrigan's counsel.

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[3] Daniel Berrigan was born in Virginia, Minnesota. Berrigan joined the Jesuits directly out of high school in 1939 and was ordained to the priesthood in 1952. From 1966 to 1970, he was the assistant director of Cornell United Religious Work (CURW), (the umbrella organization for all religious groups on campus, including the Cornell Newman Club, later Cornell Catholic Community, at which he was pastor), during which time he played an instrumental role in the national peace movement. Father Berrigan now resides in New York City and teaches at Fordham University in addition to serving as its poet-in-residence.

CHAPTER 2

Tragedy Unfolding

2.1 SUMMARY

In this chapter, the events leading up to the Deepwater Horizon oil spill are detailed and a timeline for the actual events is included. The impacts of the oil spill on the Gulf communities are described. The Exxon Valdez oil spill is recounted as well. In addition, a brief list of additional historic oil spills that have occurred over the course of the last century is included. As the reader will discover, such spills have not been confined to offshore drilling nor are they rare.

2.2 THE LEAD-UP

On February 23rd, 2009, BP asked for permission through a filing with the U.S. Minerals Management Office in New Orleans to drill two exploratory wells at a depth of 4,992 feet of water in the Gulf of Mexico. Company documents[11] state, "Under this exploration, BP Exploration and Production Inc., proposes to drill and abandon two exploratory wells in the Macondo project area." The U.S. Minerals Management Service approved the drilling proposal within weeks.

BP subcontracted the drilling to Transocean Ltd., Swiss-based, the world's largest offshore drilling company. On October 7th, 2009, Transcoean Ltd. began drilling the Macondo well with the deepwater rig, the Marianas. Within a month, however, that rig was seriously damaged by a late season hurricane and the Deepwater Horizon, which began drilling on February 6th, 2010, replaced the Marianas.

The Deepwater Horizon was built in the shipyards of Hyundai Heavy Industries in Ulsan, South Korea at a cost of $560 million. It is (was) a fifth-generation semi-submersible rig which, rather than being anchored at the drilling site, floated on massive pontoons, which sank into the ocean to a depth of approximately seventy-five feet. The rig was held in place over the drill site by a dynamic, computer-controlled system that operated eight huge thrusters each rated at approximately 7500 hp. The rig also was tethered by one steel pipe with a diameter of approximately 21 inches. In addition, the rig had living space for one hundred and thirty workers. Six diesel engines each rated at 10,000 hp powered electric generators, which produced approximately 42,000 kilowatts. The costs to operate the rig amounted to approximately $1 million per day.

From the time drilling began in February 2010, the project encountered serious problems. Four events referred to in the oil industry as "well control events" occurred prior to mid – April. Such an event can be understood as a well flirting with a blowout. Opening a deepwater well in the Gulf of Mexico involves dealing with crude oil reaching 250 degrees Fahrenheit and pressures as high as 18,000 psi. Temperatures and pressures often exceed expectations, and rock formations crumble and crack.

Though each event had been contained, the project soon became known as "a nightmare well, which has everyone all over the place."[12] Other workers offered the following assessments: "There was always an ominous feeling. This well did not want to be drilled;[13]" and "Everything that could go wrong was going wrong. This was a well from Hell.[14]"

Congressional hearings were held in June 2010, under the auspices of the House Subcommittee on Oversight and Operations.[15] Exxon-Mobile chairman and chief executive officer Tillerson offered the following opinions: "It appears to me that a number of design standards that I consider to be the industry norm were not followed. We would not have drilled the well the way they did." He went on to criticize the well's design, in particular the tethering pipe, as well as the formulation of the cement used to seal the casing and hold that pipe in place. In addition, Tillerson stated that more rigorous testing of the cement once it hardened should have been performed as well as the installation of a steel collar, which locked down the pipe in place.

Other chairmen and chief executive officers concurred including Mr. Mulva from ConocoPhillips, Mr. Odum from Shell Oil and Mr. Watson from Chevron Corporation.[16]

2.3 THE TIMELINE

The oil spill in the Gulf of Mexico has been described using the following timeline of events:

> *April 20: The Deepwater Horizon platform explodes approximately 80 kilometers off the Louisiana coast in the Gulf of Mexico. Eleven men die in the inferno that follows. Two days later, the drilling platform sinks. Two hundred and ten thousand gallons (5,000 barrels) a day of oil leak into the ocean from the burst well. As the days pass and the oil slick spreads, predictions about the magnitude of the environmental disaster spread.*
>
> *April 22nd, the Deepwater Horizon sinks, resulting in a ruptured riser pipe and releasing a torrent of crude oil and natural gas into the Gulf.*
>
> *April 29th: Louisiana Governor Bobby Jindal declares a state of emergency. The oil slick stretches across a 600-mile area. BP evaluates the results of a controlled test burn.*
>
> *April 30th, Defense Secretary gates mobilizes the Louisiana National Guard to help with cleanup and removal and to protect critical natural habitat.*
>
> *May 1st: Janet Napolitano, Homeland Security Secretary, appoints U.S. Coast Guard Commandant Thad Allen as the overall commander for the Administration's response.*
>
> *May 2nd: President Barack Obama meets with fishermen and Coast Guard officials in Venice, Louisiana. New offshore drilling leases are frozen pending a review of the accident. Thousands of square miles of federal fishing areas remain closed. BP begins drilling first relief well with an estimated completion date of 90 days.*

Figure 2.1: Deepwater Horizon rig explosion. (Oil spill picture image: `http://cgvi.uscg.mil/media/main.php` U.S. Coat Guard)

May 4th: Pentagon approves mobilization of up to 17,500 National Guard troops to help various states deal with the spill and its aftermath.

May 5th: BP states that it has stopped flow of oil from one of the leaks though no change in overall flow rate is detected.

May 8th: BP lowers a cofferdam to try and contain the oil, but at the temperatures and pressures at the sea floor, water combines with methane and gas hydrates form. The drilling of the relief well is underway. BP debates its options for stopping the flow of oil, including inserting a tube into the well or plugging it with shredded tires and golf balls.

May 9: Oil starts washing up on the beaches of islands offshore of Louisiana and Alabama.

May 11: BP, Transocean (which owned the Deepwater Horizon) and Halliburton testify at Senate hearings in Washington. An editorial cartoon by Matt Davies shows the three *chief executive officers running away from a sign on a fishhook "Gulf Spill Blame." Caption? "Dispersant."*

May 14–17: BP inserts a tube into the broken pipe, but one of the subsea robots collides with the pipe work and the tube falls out. The second attempt is more successful.

May 17th: BP begins drilling second relief well.

May 19: One month since the spill and counting. Hurricane season is predicted to begin in less than two weeks."[17]

May 20th: EPA directs BP to identify a less toxic dispersant within 24 hours and to begin using it within 72 hours. BP claims that it cannot identify a less toxic dispersant.

May 26th: BP initiates top kill procedure.

May 27th: Commandant Allen's group estimates the oil spill rate somewhere between 4000 and 8000 gallons per day. Obama Administration and Secretary of the Interior Salazar announce a six-week moratorium on deep-water drilling.

May 29th: Top kill attempt ends and characterized as total failure.

May 31st: NOAA extends the northern boundary of the closed fishing area to include over 60% of the Gulf federal waters.

June 4th: BP places containment cap over leak source.

June 15th: In an address from the Oval office, President Obama declares the oil spill as "the worst environmental disaster America has ever faced."

June 16th: BP pledges to create a $20 billion dollar fund.

June 23rd: The New Orleans federal judge struck down the Obama administration's six-week moratorium on deep-water drilling and refused a government request to delay that decision.

July 12th: After two court rulings against its six-month moratorium on new deepwater oil and gas drilling, the Obama administration on Monday announced a revised ban, saying it would end by Nov. 30 or sooner, and it would no longer be based on water depths.

July 15th: BP successfully caps the spill ending any additional significant amounts of oil spilled into the Gulf. The total amount spilled is estimated to be approximately 200 million gallons.

August 4th: NOAA estimates that approximately 75% of the oil spilled into the Gulf has been burned off, dispersed, dissolved or evaporated leaving the remaining 25% washed ashore, buried in beaches or marshes or drifting in the oceans.

August 5th: Gulf area residents challenge the NOAA claims.

August 9th: Nearly four months after the Deepwater Horizon drilling rig exploded in the Gulf of Mexico the struggle against the BP oil spill is nearly finished, in one sense. BP's ruptured well is no longer leaking. It hasn't leaked since July 15; in fact, BP said its 'bottom kill' to plug the Gulf oil spill well permanently should start later this week. BP also deposited *its first installment – $3 billion – in the Gulf escrow fund. The government estimates that 4.9 million barrels of oil flowed into the Gulf as a result of the BP spill. Much of that has been burned off, skimmed up, or has evaporated, although the exact amount remains a contentious issue. But the US estimates that about one-quarter of the oil spill total remains a threat to shore.*

September 8th: BP issues a report highlighting a four-month long internal investigation, which asserts that no single company bears sole responsibility for the accident and oil spill.

September 13th: Scientists are finding layers of oil more than 2 inches thick beneath layers of dead shrimp and other small marine creatures up to eighty miles from the accident site.

September 19th: BP completes a process called a "bottom kill" to seal the well from the oil reservoir, thereby marking the end to operations to kill the well five months after the original explosion.

2.4 IMPACT ON GULF COMMUNITIES

A worst-case scenario for the Gulf region, now that the initial wave of oiling is over, is that the effects will persist for years. Stopped after 172 million gallons entered the Gulf, according to the government estimate, the gusher is the largest offshore oil spill in U.S. history. More than 11 million gallons were burned and 1.8 million gallons of dispersant were used to sink untold amounts. Scientists believe 44.7 million gallons remain unaccounted for. The economic effect has been estimated as high as $23 billion.

As of July 27, the number of animals killed during the spill or injured and captured alive was 4,417 birds, 730 turtles, 69 dolphins and one sperm whale. But federal wildlife and fisheries experts said many more died in deep water, uncounted.

NOAA stated that in the long run, there could be a decline in the populations of predators that eat oiled animals. While the early concern was mammals and turtles that need to come to the surface to breath, whales, dolphins and sea turtles also feed in the deep ocean canyons where oil was sunk near the source of the gusher.

Millions of birds that range across the western hemisphere, winter in the marshes along the Gulf and forage the same water that has oil in it now. This winter, they will return and likely be exposed, even with projects designed to attract them elsewhere. Audubon scientists' just researched 23 areas on the Louisiana coast, finding surface oil, tar balls and oil seepage coming from below the sand. Scientists are also still finding "tar mats" just below the waterline that they say are creating new tar balls.

Additionally, scientists are concerned that the oil may have damaged the food chain, killing off small organisms, marine life and insects that animals feed on.

The oil spill has been a new challenge for everyone, for all academia, the science community, and universities as the Deepwater Horizon blowout occurred at 5,000 feet, dispensing crude oil from

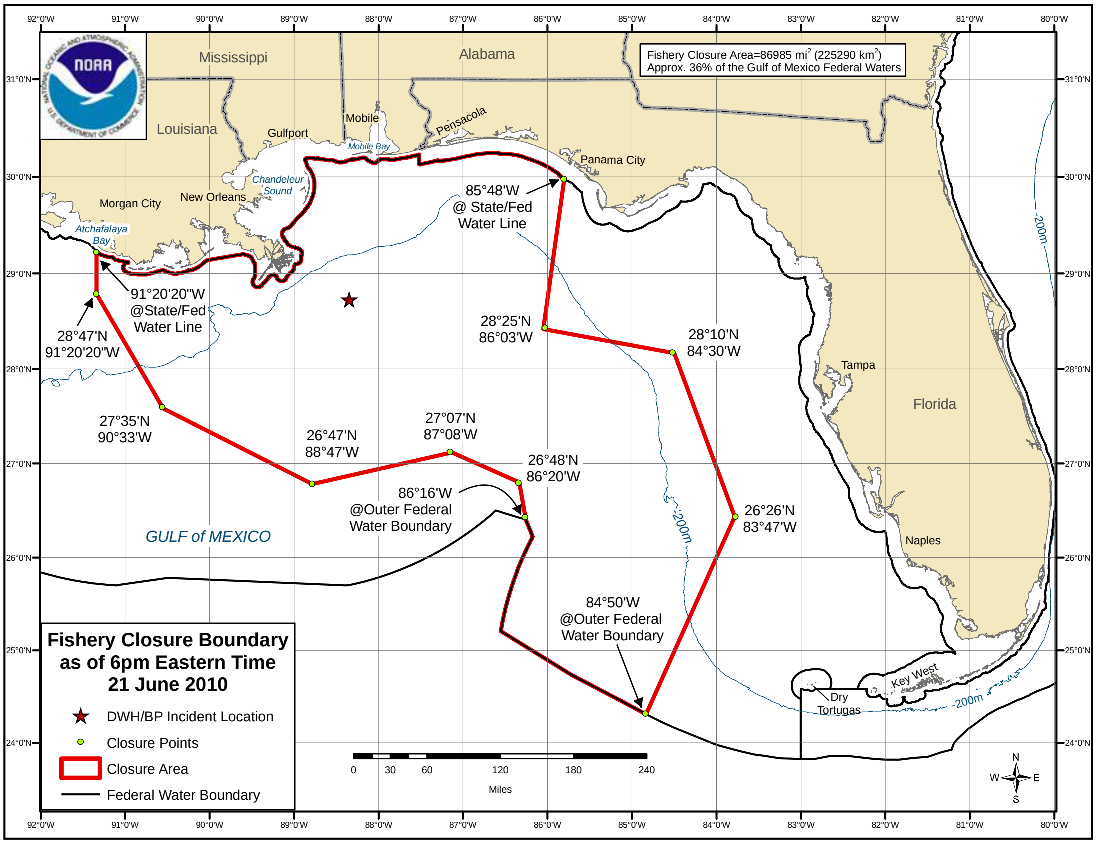

Figure 2.2: Outline of Closed Fishing Boundary `/stories2010/images/closure_map_06022010.png` (Credit: NOAA)

seafloor to surface. As a result, the uncertainty is greater in the Macondo spill. Up until this event, for the most part, researchers have studied the aftermath of surface only spills.

What scientists know about how oil spills can affect the environment – and for how long – is drawn from a range of past events, no two of which have been alike.

Comparisons with the Exxon Valdez spill, for example, can be misleading because of significant differences in the type of oil, the ecosystems affected, and the way natural processes break down oil. Many of the long-term effects may remain hidden as natural processes and chemical dispersants break up the oil into small globules dense enough to sink to the bottom. There, it has the potential to affect bottom dwellers for decades.

The Tulane Disaster Resistance Leadership Academy Assessment Team is carrying out an impact assessment in Terrebonne and Plaquemines Parishes in coastal Louisiana to help OXFAM and

Figure 2.3: Oil Soaked Brown Pelicans removed from Gulf waters. (Credit: Carolyn Cole/LA Times)

Figure 2.4: Kemp's Ridley Turtle. (Credit: Carolyn Cole/LA Times)

Figure 2.5: Oil at Pass a Loutre, Louisiana. Image shot on May 22, 2010. (Credit: NOAA)

Figure 2.6: Oil on Grand Isle, Louisiana. (Credit: NOAA)

its partners better understand the affects of the oil spill catastrophe on vulnerable coastal Louisiana communities and their resilience.

As part of this assessment, Tulane and the DRLA will collect and analyze existing baseline social and economic vulnerability of Terrebonne and Plaquemines Parishes, as well as gather information about locally identified Disaster Resilience Leaders who are helping the affected communities to respond to an cope with this crisis. The team will gather information individuals and communities in these affected parishes, with particular attention given to members of the Native American, Vietnamese and immigrant affected communities; oil and gas workers; members of the fisheries industry; and tourism. Oxfam America funds this project.

2.5 NIGERIA'S AGONY DWARFS THE GULF OIL SPILL

The Deepwater Horizon disaster caused headlines around the world, yet the people who live in the Niger delta[4] have had to live with environmental catastrophes for decades.[18]

In fact, more oil is spilled from the delta's network of terminals, pipes, pumping stations and oil platforms every year than has been lost in the Gulf of Mexico, the site of a major ecological catastrophe caused by oil that has poured from a leak triggered by the explosion that wrecked BP's Deepwater Horizon drilling platform. That disaster, which claimed the lives of 11 rig workers, has made headlines round the world. By contrast, little information has emerged about the damage inflicted on the Niger delta. Yet the destruction there provides a far more accurate picture of the price paid for drilling oil today.

On May 1st, 2010, a ruptured ExxonMobil pipeline in the state of Akwa Ibom spilled more than a million gallons into the delta over seven days before the leak was stopped. Within days of the Ibeno spill, thousands more barrels of oil were spilled when rebels attacked the nearby Shell Trans Niger pipeline. A few days after that, a large oil slick was found floating on Lake Adibawa in Bayelsa state and another in Ogoniland.

With 606 oilfields, the Niger delta supplies 40% of all the crude the United States imports and is the world capital of oil pollution. Life expectancy in its rural communities, half of which have no access to clean water, has fallen to little more than 40 years over the past two generations. Locals blame the oil that pollutes their land and can scarcely believe the contrast with the steps taken by BP and the US government to try to stop the Gulf oil leak and to protect the Louisiana shoreline from pollution.

It is impossible to know how much oil is spilled in the Niger delta each year because the companies and the government keep that secret. However, two major independent investigations over the past four years suggest that as much is spilled at sea, in the swamps and on land every year as has been lost in the Gulf of Mexico so far.

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[4] The Niger Delta, as now defined officially by the Nigerian government, extends over about 70,000 km^2 and makes up 7.5% of Nigeria's land mass. Historically and cartographically, it consists of present day Bayelsa, Delta, and Rivers States. In 2000, however, Obansanjo's regime included Abia, Akwa-Ibom, Cross River State, Edo, Imo and Ondo States in the region. Some 31 million people [1] of more than 40 ethnic groups including the Efik, Ibibio, Annang, Oron, Ijaw, Itsekiri, Igbo, Urhobo, Yoruba, and Kalabari, are among the inhabitants in the Niger Delta, speaking about 250 different dialects.

Figure 2.7: Niger Delta. (Credit: `http://www.sweetcrudemovie.com/nigerDelta.php`)

One report, compiled by WWF UK, the World Conservation Union and representatives from the Nigerian federal government and the Nigerian Conservation Foundation, calculated in 2006 that up to 1.5m tons of oil – 50 times the pollution unleashed in the Exxon Valdez tanker disaster in Alaska – has been spilled in the delta over the past half century. Last year, World Wildlife Fund calculated that the equivalent of at least 9m barrels of oil was spilled and accused the oil companies of a human rights outrage.

According to Nigerian federal government figures, there were more than 7,000 spills between 1970 and 2000, and there are 2,000 official major spillages sites, many going back decades, with thousands of smaller ones still waiting to be cleared up. More than 1,000 spill cases have been filed against Shell alone.

Last month, Shell admitted to spilling 14,000 tons of oil in 2009. The majority, said the company, was lost through two incidents – one in which the company claims that thieves damaged a wellhead at its Odidi field and another where militants bombed the Trans Escravos pipeline.[5]

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[5] More than 10,000 Nigerians have died in sectarian violence since civilian leaders took over from a former military junta in 1999. Political strife over local issues is common in Nigeria, where government offices control massive budgets stemming from the country's oil industry.

Shell, which works in partnership with the Nigerian government in the delta, says that 98% of all its oil spills are caused by vandalism, theft or sabotage by militants and only a minimal amount by deteriorating infrastructure.

Communities and environmental watchdog groups hotly dispute these claims. They mostly blame the companies' vast network of rusting pipes and storage tanks, corroding pipelines, semi-derelict pumping stations and old wellheads, as well as tankers and vessels cleaning out tanks.

The scale of the pollution is mind-boggling. The government's national oil spill detection and response agency (Nosdra) says that between 1976 and 1996 alone, more than 2.4 million barrels contaminated the environment. The sense of outrage is widespread. "There are more than 300 spills, major and minor, a year," said Bassey. "It happens all the year round. The whole environment is devastated. The latest revelations highlight the massive difference in the response to oil spills. In Nigeria, both companies and government have come to treat an extraordinary level of oil spills as the norm." Kimerling,[19] a professor of law and policy at the City University of New York, states: "Spills, leaks and deliberate discharges are happening in oilfields all over the world and very few people seem to care."

2.6 REMEMBERING THE EXXON VALDEZ

On March 24th, 1989, the tanker Exxon Valdez, en route from Valdez, Alaska to Los Angeles, California, ran aground on Bligh Reef in Prince William Sound, Alaska. The vessel was traveling outside normal shipping lanes in an attempt to avoid ice. Within six hours of the grounding, the Exxon Valdez spilled approximately 10.9 million gallons of its 53 million gallon cargo of Prudhoe Bay crude oil. Eight of the eleven tanks on board were damaged. The oil would eventually impact over 1,100 miles of non-continuous coastline in Alaska, making the Exxon Valdez the largest oil spill to date in U.S. waters.

Some 2,000 sea otters, 302 harbor seals and about 250,000 seabirds died in the days immediately following the spill. Now, researchers writing in the journal Science caution that more than a decade later, a significant amount of oil still persists and the long-term impacts of oil spills may be more devastating than previously thought.

Peterson et al.[20] compiled and analyzed the findings of dozens of previous studies. The results, Peterson says, "showed that oil has persisted in surprisingly large quantities for years after the Exxon Valdez spill in subsurface reservoirs under coarse intertidal sediments. This oil was sequestered in conditions where weathering by wave action, light and bacteria was inhibited, and toxicity remained for a decade or more." Exposure to this oil, in turn, caused additional animal deaths. Salmon, for example, had increased mortality for four years after the spill because incubating eggs had come into contact with it. Larger marine mammals and ducks, meanwhile, suffered ill effects because their prey was contaminated. An estimate suggests that shoreline habitats such as mussel beds affected by the spill will take up to 30 years to recover fully.

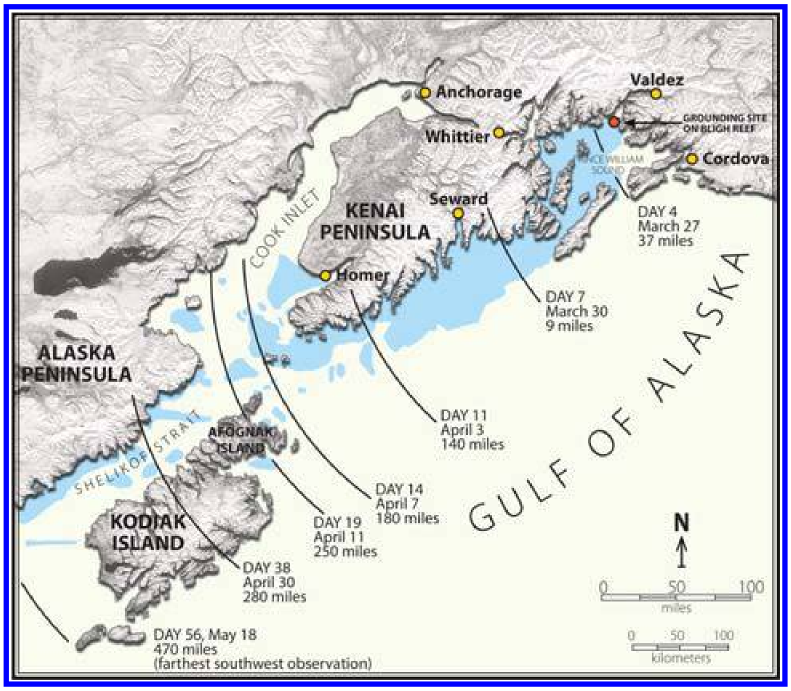

Figure 2.8: Exxon Valdez Oil Spill. (Credit: Exxon Valdez Oil Spill Trustee Council)

2.7 OTHER HISTORIC OIL SPILLS

A list of historic oil spills over the course of the last century includes the following:

Lakeview Gusher

The Lakeview Gusher is termed as the largest recorded oil well gusher in the United States of America. The Lakeview Gusher gusher took place in 1910 and reports state that the Lakeview Gusher started when high pressures led to the explosion of an oil derrick in California. This blow created a geyser of crude oil on land that spread across 30 miles. The spill could not be controlled after almost 18 months; it is known to have gushed out nearly 9 million barrels of oil.

Gulf War Oil Spill

During the 1991 Gulf War, tankers and oil terminals in Kuwait were destroyed, causing the release of an estimated 6-8 million barrels (252 – 336 million gallons) of oil into the waters of the Arabian (Persian) Gulf. Many oil wells in Kuwait were destroyed and set on fire, resulting in the release of much greater amounts of oil and combustion products to land, air, and water in Kuwait.

IXTOC 1 Oil Spill

On June 3, 1979, the 2 mile deep exploratory well, IXTOC I, blew out in the Bahia de Campeche, 600 miles south of Texas in the Gulf of Mexico. The water depth at the wellhead site is about 50 m (164 feet). The IXTOC I was being drilled by the SEDCO 135 (Sedco has since been acquired by Transocean, owner of the *Deepwater Horizon*), a semi-submersible platform on lease to Petroleos Mexicanos (PEMEX). A loss of drilling mud circulation caused the blowout to occur.

The oil and gas blowing out of the well ignited, causing the platform to catch fire. The burning platform collapsed into the wellhead area hindering any immediate attempts to control the blowout. PEMEX hired blowout control experts and other spill control experts including Red Adair, Martech International of Houston, and the Mexican diving company, Daivaz. The Martech response included 50 personnel on site, the remotely operated vehicle TREC, and the submersible Pioneer I. The TREC attempted to find a safe approach to the Blowout Preventer (BOP). The approach was complicated by poor visibility and debris on the seafloor including derrick wreckage and 3000 meters of drilling pipe. Divers were eventually able to reach and activate the BOP, but the pressure of the oil and gas caused the valves to begin rupturing. The BOP was reopened to prevent destroying it. Two relief wells were drilled to relieve pressure from the well to allow response personnel to cap it. Norwegian experts were contracted to bring in skimming equipment and containment booms, and to begin cleanup of the spilled oil. The IXTOC I well continued to spill oil at a rate of 10,000 – 30,000 barrels per day until it was finally capped on March 23rd, 1980.

Atlantic Empress and Aegean Captain Collision

On July 19, 1979, these two oil tankers collided off the coast of Trinidad and Tobago and caused the largest ship-based oil spill in history, spilling a total of 88 million gallons of oil into the Caribbean Sea.

Mingbulak Oil Spill

The largest oil spill in the history of Asia occurred in 1992 in Fergana Valley, Uzbekistan. On March 2, there was a blowout at the Mingbulak Oil Field, which caught fire and burned for two months. The well released 35,000 to 150,000 barrels per day, totaling 2 million barrels.

Nowruz Oil Field

In 1983, the Nowruz Oil Field in the Persian Gulf, Iran, was involved in a number of oil pollution incidents. On February 10, 1983, a tanker collided with a platform. The platform developed a 45-degree tilt and had to be shut down. Wave action and corrosion apparently caused the riser to collapse into the wellhead causing a spill of approximately 1,500 barrels per day. The well was not capped because the field was in the middle of the Iran/Iraq war zone. Iraqi planes attacked this platform in March and the resulting slick caught fire. The Iranians capped this well on September 18th, 1983. Eleven people were killed during the operation. In March 1983, a nearby platform was attacked with rockets by Iraqi helicopters. The platform burned and spilled oil at an initial rate of approximately

5,000 barrels per day. The rate slowed to about 1,500 barrels per day in the two years before the well was capped. In May 1985, the fire was extinguished and the well was plugged with the assistance of divers. Nine men died during these operations. Approximately 733,000 barrels of oil spilled into the sea as a result of this incident. It is estimated that the rate of oil leaking into the Persian Gulf in mid-May of 1983 was between 4,000 and 10,000 barrels per day due to more war-related activity or the collapse of burning platforms. As a result of this incident, a cooperative program for large-scale trajectory modeling was developed between the National Oceanic and Atmospheric Administration and Kuwait's Environment Protection Council under the Ministry of Public Health.

ABT Summer

On May 28th, 1991, there was an explosion aboard the ABT Summer, a Liberian supertanker. The explosion resulted in five deaths and a burning 80 square mile oil slick about 900 miles off the coast of Angola.

Castillo de Bellver

The *Castillo de Bellver* incident resulted in the loss of between 160,000 and 190,000 tons of crude oil. Not only was this the largest spill to date in South Africa, but also, it occurred near an area of great ecological sensitivity and in the vicinity of important commercial fishing grounds. Despite this, observations during the spill and on subsequent surveys indicated that environmental damage was minimal. This can only be attributed to the favorable direction of the wind, which caused the slick to move offshore and into the Benguela current, thus allowing for its natural dispersion. Some concern remains over oil still trapped in the sunken stern section.

Amoco Cadiz

On March 16th, 1978, the Amoco Cadiz ran aground on Portsall Rocks, three miles off the coast of Brittany due to failure of the steering mechanism. The vessel had been en route from the Arabian Gulf to Le Havre, France when it encountered stormy weather, which contributed to the grounding. The entire cargo of 1,619,048 barrels, spilled into the sea. A slick 18 miles wide and 80 miles long polluted approximately 200 miles of Brittany coastline. Beaches of 76 different Breton communities were oiled.

The isolated location of the grounding and rough seas restricted cleanup efforts for the two weeks following the incident. Severe weather resulted in the complete break up of the ship before any oil could be pumped out of the wreck. As mandated in the "Polmar Plan," the French Navy was responsible for all offshore operations while the Civil Safety Service was responsible for shore cleanup activities. Although the total quantity of collected oil and water reached 100,000 tons, less than 20,000 tons of oil was recovered from this liquid after treatment in refining plants.

MT Haven

MT Haven, formerly Amoco Milford Haven, was a VLCC (very large crude carrier), leased to Troodos Shipping (a company ran by Lucas Haji-Ioannou and his son Stelios Haji-Ioannou). In 1991, while loaded with 144,000 tons (1 million barrels) of crude oil, the ship exploded, caught fire and sank off the coast of Genoa, Italy, killing six Cypriot crew and flooding the Mediterranean with up to 50,000 tons of crude oil. It broke in two and sank after burning for three days, and for the next 12 years, the Mediterranean coast of Italy and France was polluted, especially around Genoa and southern France.

2.8 OTHER CONTAMINATION

Oceans suffer from far more than an occasional devastating spill. Disasters make headlines, but hundreds of millions of gallons of oil quietly end up in the seas every year, mostly from non-accidental sources. Used engine oil can end up in waterways. An average oil change uses five quarts; one change can contaminate a million gallons of fresh water. Much oil in runoff from land and municipal and industrial wastes ends up in the oceans. Every year oily road runoff from a city of 5 million could contain as much oil as one large tanker spill. Every year, bilge cleaning and other ship operations release millions of gallons of oil into navigable waters, in thousands of discharges of just a few gallons each. Air pollution, mainly from cars and industry, places hundreds of tons of hydrocarbons into the oceans each year. Particles settle, and rainfall washes hydrocarbons from the air into the oceans. Some ocean oil “pollution” is natural. Seepage from the ocean bottom and eroding sedimentary rocks releases oil. Only about 5 percent of oil pollution in oceans is due to major tanker accidents, but one big spill can disrupt sea and shore life for hundreds of miles. Offshore oil production can cause ocean oil pollution, from spills and operational discharges.

CHAPTER 3

Engineering Ethics

3.1 SUMMARY

In this chapter, we explore the field of engineering ethics including traditional approaches as well as different modern ideas. Our look at traditional ethical analysis includes Utilitarianism, rights based approaches and virtue based approaches. Modern paradigms based upon our understanding of freedom, chaos, globalism, a morally deep world and an ethic of love are included. Having considered the ethical foundations, we then describe various codes of ethical conduct as offered by various professional engineering and engineering education societies. The case is then made for a more encompassing ethic.

3.2 INTRODUCTION TO ENGINEERING ETHICS

Engineers make choices in nearly all aspects of their work. As we move farther into the 21st century, engineers will become more directly involved in issues of conflict, development and environmental sustainability. The present work confronts those issues head on and offers a variety of frames of reference for decision-making including traditional approaches used in engineering throughout the modern era as well as new ideas, which have just recently been applied to the professions.

As described by NSPE, "engineering ethics is (1) the study of moral issues and decisions confronting individuals and organizations involved in engineering and (2) the study of related questions about moral conduct, character, ideals and relationships of peoples and organizations involved in technological development."[21] Harris et al.[22] describe their approach to engineering ethics as bridging the gap between theory and practice using current case studies available such as Hurricane Katrina and global warming. Fledderman seeks to provide a text and a resource for the study of engineering ethics and to help future engineers be prepared for confronting and resolving ethical dilemmas that they might encounter during their professional careers.[23] Martin and Schinzinger provide an introduction to the key issues in engineering ethics, taking account of both specific organizational contexts and broader technological trends.[24] Baura approaches engineering ethics from an industrial perspective.[25] Vesilind et al. focuses upon the special nature of responsibility that engineers has towards the environment.[26] There are many other texts and websites which focus upon engineering ethics.[27]

In the present chapter, a review of several recent efforts is offered with the aim of developing several additional paradigms for ethical decision making including ones based on freedom, on chaos, on the concept of a morally deep world, on a global ethic and lastly one based on love. More detailed descriptions of the different approaches are available in previous works.[28,29,30]

3.3 ENGINEERING ETHICS REVISITED

In this next section, we shall look in more detail at several of the existing applied ethical theories that are used in the practice of engineering today. We shall follow that up with a brief look at several new theories that have also been described.

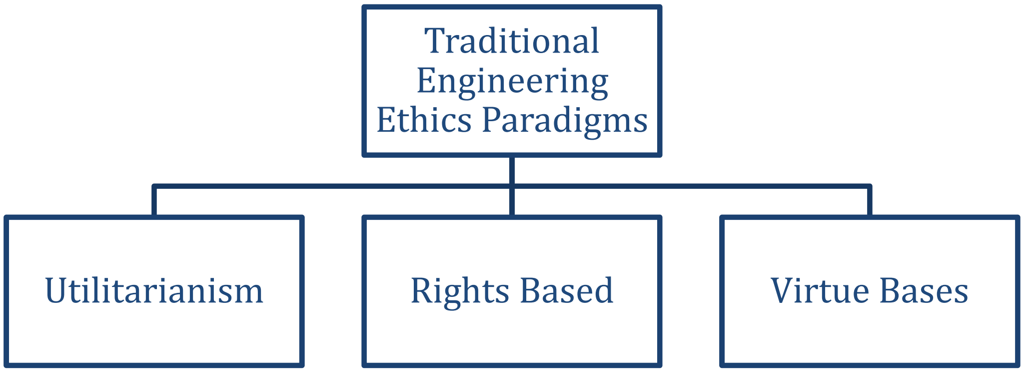

Figure 3.1: Schematic of Traditional Engineering Approaches.

3.3.1 TRADITIONAL APPLIED ETHICS

Modern engineering bases most of its ideas when deciding ethical dilemmas on what we may call traditional applied ethics theories including: (1) utilitarianism,[31] (2) rights-based ethics;[32] and (3) virtue ethics[33] to name a few. As a starting point for the present section, a brief description of each of these applied ethical theories shall be presented.

Utilitarianism is the idea that the moral worth of an action is determined solely by its contribution to happiness or to pleasure, i.e., utility) summed up for all interested persons. Often adherents describe utilitarianism by the phrase "the greatest good for the greatest number," though on occasion, it is further simplified to simply choosing "the greatest good."

Rights-based approaches also have their roots with ancient philosophers concerned with the concept of justice, as well as natural law philosophers who recognized a potential for certain rights inherent in human nature. Modern notions of natural rights are most closely associated with Locke[34] and his contention that human beings are entitled to life, liberty and property, which in contemporary theory form the basis of what are referred to as universal human rights.[35]

Virtue ethics "emphasizes the virtues, or moral character, in contrast to the approach which emphasizes duties or rules (deontology) or that which emphasizes the consequences of actions (consequentialism or here, Utilitarianism)."[36]

These traditional approaches have been encapsulated in many of our various engineering codes of ethics. An engineering decision based in Utilitarianism would seek to maximize the good while one taking a rights based approach would focus on preserving the dignity of each individual who is affected by the decisions. Lastly, an engineer whose ethical code is based in a virtue ethics approach would concentrate on the actual character of the decision maker.

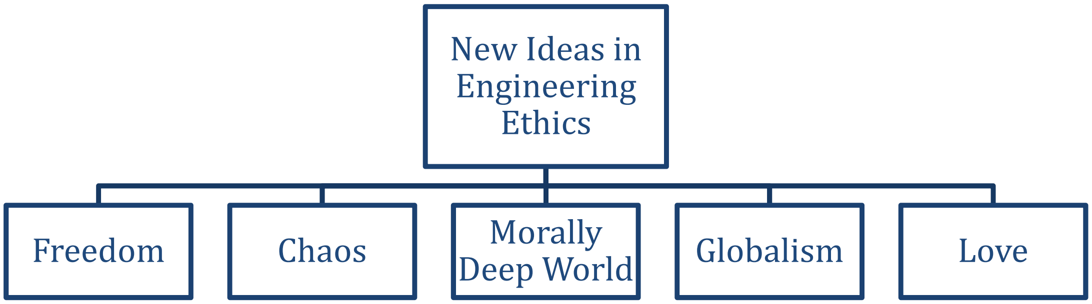

Figure 3.2: Schematic of Several New Approaches in Ethics.

3.3.2 ENGINEERING ETHICS AND FREEDOM

A commonly held perspective is that Western culture is a body of knowledge derived from reason with the foundation of reason serving as a springboard towards a vast accumulation of understanding related to reality or nature, including human nature.[37] This understanding is represented in several core ideals and values, which include individualism, happiness, rights, and capitalism as well as science and technology. Individualism means emphasis on the individual person. Western culture's embrace of individualism stems from its embrace of reason because the individual — and only the individual — has the ability to reason.[38]

Implications of individualism give rise to our understanding of freedom. One effort to fully explore the notion of freedom can be found in existentialist theory. An existentialist conception of individuality may give rise to the following set of questions relevant for our search for approaches to confronting serious questions in the 21st century:

What is human freedom?

What can the absolute freedom of absolute individuals mean?

What is human flourishing or human happiness?

What general ethic or way of life emerges when we take our individuality seriously?

What ought we to do?

What ethics or code of action can emerge from a position that takes our individuality seriously?

Our actions, though free, are constrained by our situation in a community with all its relationships and obligations. The implications of this perspective for engineering and engineering education are several-fold. At the very least, it broadens the notion of whom we serve. In essence, we now serve our clients, ourselves and the rest of humanity. In addition, it includes all three into discussions from the outset and changes the idea that we solve problems identified by others. In fact, we all are involved in the framing of the problem from the outset. In summary, freedom as constructed from an existentialist perspective, must take on the responsibility of choosing for all of humankind, desire and work for the freedom of all humanity, and create ourselves within the context of the relationships and obligations we have to others

Nussbaum[6] has continued to develop the notion of freedom.[39] According to Nussbaum, "At the heart of this tradition is a twofold intuition about human beings: namely, that all, just by being human, are of equal dignity and worth, no matter where they are situated in society, and that the primary source of this worth is a power of moral choice within them, a power that consists in the ability to plan a life in accordance with one's own evaluation of ends." To these two ideas is linked one more, that "the moral equality of persons gives them a fair claim to certain types of treatment at the hands of society and politics. . . . [T]his treatment must do two . . . things [:] respect and promote the liberty of choice, and . . . respect and promote the equal worth of persons as choosers."

A necessary component of Nussbaum's approach then is the list of basic capabilities that answer the following question, "What activities characteristically performed by human beings are so central that they seem definitive of a life that is truly human?" Nussbaum's list includes the following:

> The ability to live life to its natural end;
>
> Maintaining health and integrity of the body;
>
> The ability to move freely about and be free from the threat of violence;
>
> Being able to use the senses; being able to imagine, to think, and to reason;
>
> Being able to have attachments to things and persons outside ourselves;
>
> Being able to love those who love and care for us while not having one's emotional developing blighted by fear or anxiety;
>
> Being able to form a conception of the good and to engage in critical reflection about the planning of one's own life;
>
> Being able to live for and in relation to others, to recognize and show concern for other human beings, to engage in various forms of social interaction;

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[6] Martha Nussbaum is an American philosopher with a particular interest in ancient Greek and Roman philosophy, political philosophy and ethics. Dr. Nussbaum is currently the Ernst Freund Distinguished Service Professor of Law and Ethics at the University of Chicago, a chair that includes appointments in the Philosophy Department, the Law School, and the Divinity School. She previously taught at Harvard and Brown where she held the rank of university professor.

Being able to imagine the situation of another and to have compassion for that situation;

Having the capability for both justice and friendship;

Being able to be treated as a dignified being whose worth is equal to that of others;

Being able to live with concern for and in relation to animals, plants, and nature;

Being able to laugh, to play, to enjoy recreational activities ; and

Possessing control over one's environment.

Nussbaum's ideas have important relevance for the engineering profession. They call into question any engineering design whose main goal is to destroy or inflict pain and suffering. It brings the notions of compassion and genuine friendship into our considerations as it does justice. It challenges us to engage in a critical reflection of our work.

3.3.3 ENGINEERING ETHICS AND CHAOS

Over the course of the last two centuries, science has undergone a major reshuffling. The work of Einstein and others has shown that Newtonian science adequately describes a limited number of idealized problems at best.[40] Many as potentially supplanting the classical mechanics of Newton see a new science, the science of chaos. Chaos is a science of disorder, probabilities and non-linearities.[41] Most interestingly, it appears to be a more accurate description of nature, for Nature's essence is chaos.[42] The winds of the atmosphere, the streams of the oceans, the sliding of the surface platelets all are chaotic.

Chaos also describes the deposition of river silt along the Mississippi Delta, the flow of water through the giant oak trees, and the flow of blood in the arteries and veins of human beings. The nonlinear interaction of one human being with another is also chaotic. To imagine the impact that chaos may have on ethical analysis, we will examine an ethic borrowed from a consideration of the environment and based on a Newtonian perspective.

In *Sand County Almanac*,[43] Leopold[7] wrote: "All ethics so far evolved rest upon a single premise: that the individual is a member of a community of interdependent parts. Ecology simply enlarges the boundaries to include soils, waters, plants, and animals, or collectively the land. In short, a land ethic changes the role of Homo *sapiens* from conqueror of the land community to plain member and citizen of it. It implies respect for his fellow members and also respect for the community as such." Leopold went on to formulate "The Land Ethic:"

---

[7] Aldo Leopold was an American ecologist, forester, and environmentalist. He was a professor at the University of Wisconsin and is best known for his book, A Sand County Almanac (1949). Leopold was influential in the development of modern environmental ethics and in the movement for wilderness conservation. His ethics of nature and wildlife preservation had a profound impact on the environmental movement, with his bio-centric or holistic ethics regarding land. He emphasized biodiversity and ecology and was a founder of the science of wildlife management.

> *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."*

According to Leopold, acting ethically is a matter of concern both for us and for others with whom we are in some sort of community. In biology or ecology, community refers to an interacting group of various species in a common location. For example, a forest of trees and undergrowth plants, inhabited by animals and rooted in soil containing bacteria and fungi, constitutes an integral community. Extending the notion of community in this way is consistent with the pattern evidenced in human society over the centuries. We have progressively enlarged the boundaries of our understanding of community and recognized the membership of slaves, foreigners, etc., those for whom membership was not extended at earlier times in history. Leopold's land ethic then "simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land."

Leopold's view of the natural world is apparent when he asserts that the *stability* of Nature is disrupted by the interference of humankind. He believed that Nature left to its own design will "naturally" opt for the stable or equilibrium position and that it is Man who disrupts this stability, challenges its integrity, and causes a natural world with diminished beauty. If we shift our model of the natural world from its historic deterministic base to one that embraces chaos, a new environmental ethic developed by the author is suggested:

> *A thing is right when it tends to allow the natural world and all the entities thereof, to thrive in richness and diversity, and to experience change. It is wrong when it tends otherwise.*[44]

Note that there are three elements to this new ethic:

> Richness here refers to the richness of experience of the various entities that make up the natural world;
>
> Diversity refers to wide variety in plant and animal species. An action that would yield an enhancement of the variety of species that exist in a given ecosystem would be in accord with the new environmental ethic; and
>
> Change as the restraint of change is a violation of the processes that model the natural world.

Consider the implications for the engineering profession particularly in our sense of responsibility towards the health of the natural world. Rather than seeing Nature as s system, which has an equilibrium state if only, we (i.e., humankind) would not interfere,

Nature now is seen as a dynamic system in which change is allowed and the emphasis is shifted to nurturing diversity.

3.3.4 ENGINEERING ETHICS AND A MORALLY DEEP WORLD

The concept of a morally deep world[45] was developed within the framework of environmental ethics. Johnson discusses how non-sentient land can count morally and focuses upon the concept of a living being. For Johnson, a living being is best thought of not as a thing of some sort but as a living system, an ongoing life-process. A life-process has a character significantly different from those of other processes such as thermodynamics processes for example. Our character, as living beings, is the fundamental determinant of our interests. Johnson adds further:

> "The interests of a being lie in whatever contributes to its coherent effective functioning as an on-going life-process. That which tends to the contrary is against its interests….moral consideration must be given to the interests of all living beings, in proportion to the interest. Some living systems other than individual organisms are living entities with morally considerable interests. …All interests must be taken into account."

Often in ethics cases, two very different perspectives dominate the deliberations. On one side of the debate is atomism, a view that moral assessment applies only to individuals. On the other side is holism, a view that collectives or whole are subject to moral appraisal. In a morally deep world, the view is shortsighted morally if one adopts either a holistic or atomistic. No one (holistic or atomistic) interest has priority over the other. There is an inevitable tension between atomistic and holistic ethics. Sometimes the interests of the biotic community will outweigh the interests of the individual, while at other times, it is the interests of the individual, which are paramount.

One criticism often offered of a morally deep world perspective is that it prevents any action that will affect a community. On the contrary, though a morally deep perspective does assert actions that violate vital interests of the community or erosion of its self- identity should be avoided, it requires active participation in the protection of the essential functions and the maintenance of the viability of life processes. Rather than calling for inaction, a morally deep world perspective suggests contemplation followed by direct and specific responses.

Given a shift to a morally deep world paradigm, a new engineering code of conduct is outlined. The majority of existing codes are structured in similar if not identical ways with fundamental principles supported by fundamental canons.

The NSPE code[46] states:

> *Engineers, in the fulfillment of their professional duties, shall hold paramount the safety, health, and welfare of the* ***public****.*

That same structure will be incorporated into the present work. For a morally deep world, the first fundamental canon and rule of practice is specified as:

> *Engineers, in the fulfillment of their professional duties, shall hold paramount the safety, health and welfare of the* ***identified integral community****.*

Contrasting with the NSPE code[8], the fundamental difference between an ethical codes based on a morally deep world versus the present codes is the replacement of the "public" by the "identified integral community."

3.3.5 ENGINEERING AND GLOBALISM

There is little doubt that the world is becoming more and more globalized. The current form of globalization, based upon neo-liberalism, free trade and open markets, has sparked much debate throughout the world. Some critics would argue that the interests of powerful nations and corporations are shaping the terms of world trade. Proponents would argue that globalization has led to massive increases in the world's wealth while critics would suggest that while a few people are becoming increasingly wealthy, a greater percentage of the world's population is become poorer.

Discussion on globalism primarily focuses on economic globalism. This phenomenon seems particularly important in the practice of engineering, and we shall explore the implications of this form and suggest an ethical framework for making decisions in light of its existence.

With respect to economic globalism, the number of people living in absolute poverty has increased from a billion five years ago to 1.2 billion today according to a collaborative report prepared by the World Bank, the International Monetary Fund, the Organization for Economic Cooperation and Development and the United Nations.[47] For more than 30 of the poorest national economies, real per capita incomes have been falling for the past 35 years. Asia is the only region in which poverty rates decreased during the past five years. Economic progress in Latin America was made ineffective by the increase in inequality among the various classes of society. People in the industrial countries now are 74 times richer than those in the poorest. The wealth of the three richest men in the world is greater than the combined GNP of all of the least developed countries – 600 million people. This impoverishment has occurred at a time when globalization was supposed to have launched the poor into sustained economic growth.

On September 4, 1993, for the first time in the history of religion, delegates to the Parliament of the World's Religions in Chicago adopted a "Declaration toward a Global Ethic." On September 1, 1997, again for the first time, the InterAction Council of former heads of state or government called for a global ethic and submitted to the United Nations a proposed "Universal Declaration of Human Responsibilities," designed to underpin, reinforce and supplement human rights from an ethical angle. In addition, the third Parliament of the World's Religions, held in Cape Town in December 1999, issued "A Call to Our Guiding Institutions," based on the Chicago Declaration.

What is in fact meant by a *global ethic*?[48] A global ethic describes the core of common values, standards and basic attitudes or alternatively a minimal basic consensus relating to binding values, irrevocable standards and moral attitudes, which can be affirmed by all religions despite their differences and can also be supported by non-believers. In many ways, it is a call for a change of

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[8] NSPE Code of Ethics for Engineers states: "Engineers, in the fulfillment of their professional duties, shall: Hold paramount the safety, health, and welfare of the public." (`http://www.nspe.org/Ethics/CodeofEthics/index.html`)

consciousness. In its widest sense, it includes all our sensations, thoughts, feelings, and volitions – in fact, the sum total of our mental life.

The implications for a global ethic in engineering are linked perhaps most directly to the profession's view of its responsibility towards the poor. A series of questions immediately come forward. Is the growing gap between the rich and the poor any concern for engineering? Is it a concern only for us here in the United States or does the sense of responsibility extend beyond our borders to countries such as Haiti? Are our responsibilities different depending upon whether or not it is a politically driven disaster or naturally occurring?

3.3.6 ENGINEERING AND LOVE

Theologians, philosophers, and applied ethicists have explored the idea of an ethic of love. Fletcher[49] suggested that what is right in one case might be wrong in another and it is, therefore, up to the individual to decide what is the right thing to do in each situation. He suggests three ethical approaches: legalism, antinomianism and situationism. According to Fletcher, legalism occurs when "one enters into every decision-making situation encumbered with a whole apparatus of prefabricated rules and regulation." Antinomianism, at the other end of the spectrum, rejects all pre- fabricated rules with each decision seen as an existential dilemma. Somewhere in the middle of these two opposites lies situationism in which both rules and rejecting rules are set aside and the decision for the particular situation is based in our desire to nurture our concept of love.

Dudley has offered a somewhat similar ethic to an ethic based on love, that is, one based on care.[50] An ethic of care and responsibility develops from an individual's feeling of interconnectedness with others. It is contextual and arises from experience. It is characterized by nurturance and an emphasis on responsibilities to others. An ethic of justice, on the other hand, is an expression of autonomy. It is formulated in terms of universal, abstract principles and is characterized by rationality and an emphasis on individual rights. Some describe an ethic of caring as a "female" approach to morality and an ethic of rights and justice as a "male" approach.

Countless sages, scholars, poets, philosophers, theologians and others have tried to define love throughout the ages. Let us use the following description of three aspects of love, which may impact the manner in which we reach decisions.

> *Agape*: love that promotes overall well being when confronted by that which generates ill-feeling (i.e., returning good for ill). It is an unconditional love directed towards one's neighbor, which is not dependent on any lovable qualities that the object of love possesses. *Agape* is the love that brings forth caring regardless of circumstance. In a Christian context, Lewis metaphorically compares love with a garden, charity with the gardening utensils, the lover as the gardener, and God as the elements of nature. God's love and guidance act on our natural love (that cannot remain what it is by itself) as the sun and rain act on a garden: without either, the object (metaphorically the garden; realistically love itself) would cease to be beautiful or worthy.

> *Eros*: love that promotes overall well being by affirming the valuable or beautiful.
>
> According to some interpretations of Plato, although *eros* is initially felt for a person, with contemplation, it becomes an appreciation of the beauty within that person, or even becomes appreciation of beauty itself.[14] Plato also said *eros* helps the soul recall knowledge of beauty, and contributes to an understanding of spiritual truth.
>
> *Philia*: love that promotes overall well being when cooperating with others. In his ***The Rhetoric***, Aristotle defines the activity involved in *philia* as: "wanting for someone what one thinks good, for his sake and not for one's own, and being inclined, so far as one can, to do such things for him."[15] Cooper argues that this indicates: "that the central idea of philia is that of doing well by someone for his own sake, out of concern for *him* (and not, or not merely, out of concern for oneself). Aristotle takes *philia* to be both necessary as a means to happiness ("no one would choose to live without friends even if he had all the other goods" and noble in itself.

Putting the three ideas together, we have the basic framework for reaching ethical decisions. Our work then must promote the overall well being of all, including our perceptions of friends, and foes. It challenges us to reflect on the words found in nearly all universal wisdom traditions. It calls for moving beyond that false dualism, false as who is to say what actually is good and what is ill? Can we ever really know with certainty?

The last category of love, *philia*, challenges us to see the world in a different way, or in the words of Thomas Berry, as a *communion of subjects*.[51] Berry's most famous quotation is:

> *The Universe and thus the Earth is a communion of subjects, not a collection of objects.*

By communion, Berry was referring to intimacy or a feeling of emotional closeness, a connection, especially one in which something is communicated or shared. The shift from object to subject is also profound. An object is something visible or tangible; something that can be seen or touched, a focus of somebody's attention or emotion; or a goal or purpose. By subject, the reference is to the essential nature or substance of something as distinguished from its attributes.

The implications for an ethic in engineering are linked perhaps most directly to the profession's view of its responsibility towards the poor. A series of questions immediately come forward. Is the growing gap between the rich and the poor any concern for engineering? Is it a concern only for us here in the United States or does the sense of responsibility extend beyond our borders to countries such as Haiti? Are our responsibilities different depending upon whether or not it is a politically driven disaster or naturally occurring?

3.4 ENGINEERING CODES TODAY

At the start of the 21st century, there are as many different codes of conduct in engineering as there are engineering disciplines and specialties. One professional society, the National Society for

Professional Engineers (NSPE)[9], has offered one general code, which is widely employed today in all the disciplines as well as in engineering education. The NSPE Code of Ethics[52] consists of a preamble followed by a listing of fundamental canons and then rules of practice. The very first canon cautions engineers in the fulfillment of their professional duties, to "hold paramount the safety, health and welfare of the public." As a result, the first rule of practice states that engineers shall "hold paramount the safety, health, and welfare of the public." Note that the explicit requirements focus on the public only though presumably concern for the natural world is included implicitly though only as it affects humankind.

The American Society of Mechanical Engineers (ASME) sets forth a similarly constructed code of ethics with fundamental principles followed by fundamental canons.[53] The first principle states that engineers uphold and advance the integrity, honor, and dignity of the Engineering profession by using their knowledge and skill for the enhancement of human welfare. The supportive fundamental canon states engineers shall hold paramount the safety, health and welfare of the public in the performance of their professional duties.

The American Society of Civil Engineers (ASCE) does at least mention the environment in its code.[54] According to ASCE, engineers uphold and advance the integrity, honor and dignity of the engineering profession by using their knowledge and skill for the enhancement of human welfare and the environment (fundamental principle) and shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties (fundamental canon). There is no explanation of what is meant by the enhancement of human welfare or enhancement of the environment.

In November 1996, the ASCE Board of Direction adopted the following definition of sustainable development: "Sustainable development is the challenge of meeting human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and the natural resource base essential for future development."[55] Note the emphasis on resources and development.

The Institute of Electrical and Electronics Engineers (IEEE) Code of Ethics states that its members accept responsibility in making engineering decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment.[56] Here, an interesting notion of responsibility towards the environment is described. It is not in opposition to the IEEE code to endanger the public or the environment only to not disclose promptly factors that might endanger the public or the environment.

The Institute of Industrial Engineers (IIE) endorses the Canon of Ethics provided by the Accreditation Board for Engineering and Technology (ABET) whose first principle is that "engineers uphold and advance the integrity, honor and dignity of the engineering profession by using their knowledge and skill for the enhancement of human welfare and whose first canon is engineers shall

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[9] The National Society of Professional Engineers (NSPE) is the national society of engineering professionals from all disciplines that promotes the ethical and competent practice of engineering, promotes licensure and enhances the image and well-being of its members. Founded in 1934, NSPE serves more than 54,000 members and the public through 53 state and territorial societies and more than 500 chapters.

hold paramount the safety, health and welfare of the public in the performance of their professional duties."[57] ABET is the accrediting body for all engineering and engineering technology programs in the United States and thus has an important impact on the training of tomorrow's engineers and engineering educators.

Members of the American Institute of Chemical Engineers (AIChE) are challenged to uphold and advance the integrity, honor and dignity of the engineering profession by being honest and impartial and serving with fidelity their employers, their clients, and the public; striving to increase the competence and prestige of the engineering profession; and using their knowledge and skill for the enhancement of human welfare.[58] To achieve these goals, AIChE members shall hold paramount the safety, health and welfare of the public and protect the environment in performance of their professional duties. There is neither elaboration on the ideas of enhancing human welfare or protecting the environment nor an identification on from whom or what shall it be protected.

Many other engineering disciplines exist, each with their own codes for ethical conduct. As can be seen from this review, there is little discussion of what enhancing human welfare actually means or how it might be actually quantified or measure. A large percentage of the codes do not explicitly identify the environment as an important stakeholder in discussions of the ethics of engineering choices. Equally as troubling, those codes that do mention the environment refer to the idea of enhancing nature or promoting sustainable development, which is based solely upon meeting human needs. A select few number of codes do mention a responsibility to protect the environment but without identifying from whom or from what.

There are many other engineering disciplines at present, each with its own code of conduct or ethics, which describes the responsibilities of the profession. Most focus heavily on the sense of responsibility engineering has towards employers, society in general and towards other professional engineers.

3.5 CONCLUDING THOUGHTS

Engineering ethics is the field of applied ethics that examines and sets standards for engineers' obligations to the public, their clients, employers and the profession. Engineering has sought guidance in resolving ethical dilemmas through a host of different ethical approaches including Utilitarianism, rights-based theories and virtues based theories to name just a few. Though these traditional approaches have been widely accepted and practiced, various new approaches have also been explored including the ethics of freedom, chaos, globalism, a morally deep world and the ethics of caring or love.

The various traditional approaches taken have led to a series of engineering ethical codes, varying from discipline to discipline, society to society. In their totality, the codes of ethics point to a definite conception or understanding of the natural world, different than our science provides us with now. We are at once removed from membership in the natural world as there is a listing of responsibilities of the engineering profession to humankind and if it exists at all a sense of responsibility to the natural world only in so far as it can provide something for us. We are not products of the Earth but somehow placed on it with a focused plan of action set in place to tame it, control it, and to transform it into what best suits are interests.

Perhaps it is time for new look at our sense of connection to the Earth. Perhaps this notion that somehow we are so very different, so very important, so very special has inevitable lead to our understanding of the Earth as a collection of objects to be used as we see fit. After all, collections have no value unless we can ascribe value.

Perhaps it is equally as important to examine what we actually mean by enhancing human welfare? How do we propose to do that? A simple and oft-repeated response is to look at the Gross Domestic Product (GDP) or as it was known previously, the Gross National Product (GNP). Certainly if we as a profession assist societies or cultures increase their GDP, we have made a value contribution or have we? I am reminded of a speech delivered by Robert Kennedy at the University of Kansas in May 1968:[59]

> "Our Gross National Product, now, is over $800 billion dollars a year, but that Gross National Product - if we judge the United States of America by that - that Gross National Product counts air pollution and cigarette advertising, and ambulances to clear our highways of carnage. It counts special locks for our doors and the jails for the people who break them. It counts the destruction of the redwood and the loss of our natural wonder in chaotic sprawl. It counts napalm and counts nuclear warheads and armored cars for the police to fight the riots in our cities. It counts Whitman's rifle[10] and Speck's knife,[11] and the television programs, which glorify violence in order to sell toys to our children. Yet the gross national product does not allow for the health of our children, the quality of their education or the joy of their play. It does not include the beauty of our poetry or the strength of our marriages, the intelligence of our public debate or the integrity of our public officials. It measures neither our wit nor our courage, neither our wisdom nor our learning, neither our compassion nor our devotion to our country, it measures everything in short, except that which makes life worthwhile."

The notions of increasing GNP or GDP through the consequences of senseless acts of violence have given me great pause. What do my creations in engineering contribute to society or the planet as a whole? How many of the objects or processes that I have designed in my career can be seen in a parallel light as Whitman's rifle, Speck's knife, the napalming of villages in Vietnam or the laying of landmines in Serbia? Using the engineering codes of ethics as they are now constructed, it is not clear to me how I might judge the ethics of that which I have been asked to design and create.

In the final analysis, it is this very issue has generated my desire to find a new ethic for the engineering profession, one that does countenance "the health of our children, the quality of their

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[10] Charles Joseph Whitman was a student at the University of Texas at Austin and a former Marine who killed 16 people and wounded 32 others during a shooting rampage on and around the university's campus on Aug. 1, 1966. Whitman killed three of his victims inside the university's tower, and 10 others from the 29th floor observation deck of the University's 307-foot administrative building; one died a week after the shooting from her wounds.

[11] Richard Franklin Speck was a mass murderer who systematically tortured, raped and murdered eight student nurses from South Chicago Community Hospital in Chicago, Illinois on July 14, 1966.

education or the joy of their play as well as "include the beauty of our poetry or the strength of our marriages, the intelligence of our public debate or the integrity of our public officials."

CHAPTER 4

Complex Systems

4.1 SUMMARY

In engineering, we are very comfortable in modeling linear phenomena and linear systems. Over the course of the last few centuries, we have developed a vast array of analytical tools, which help us dissect and analyze such systems. We shall consider concepts beyond the definition of linearity including the idea of a stationary system in time, reductionism, equilibrium and the response to small perturbations about the equilibrium point(s). We shall then go on to describe complex systems through a consideration of some of the modern tools used to analyze complex systems.

4.2 COMPLEX SYSTEMS THEORY

Perhaps it is useful to start with what complex systems are not. Such systems are not linear, not stationary, not subject to reductionism, not prone to equilibrium and thus not subject to analysis using perturbation theory. Let us examine each of these characteristics or more properly stated non-characteristics in a bit more detail.

4.2.1 LINEAR SYSTEMS

A linear system is a discrete system, which is explicitly an algorithm, wherein the input is transformed to the output. The output is said to be transformed by the operator L() that then describes discrete system. With the presence of a feedback loop, the model forms the basis for what is termed control theory. In a general sense, there are four kinds of feedback loops systems: natural systems with natural feedback, natural systems with human devised feedback, human devised systems with human devised feedback and human devised systems with human devised feedback.

Conversely, a complex system exhibits no such simple relationship between input (cause) and output (effect).

4.2.2 STATIONARY SYSTEMS

A stationary system is one in which the parameters which describe the behavior of the system are not functions of time, that is, such parameters are time invariant. More formally from mathematical sciences, a stationary process is a stochastic process whose joint probability distribution does not change when shifted in time or space. As a result, parameters such as the mean and variance, if they exist, also do not change over time or position.

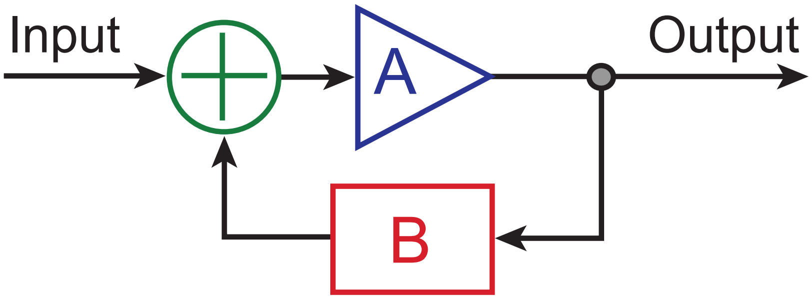

Figure 4.1: Ideal feedback model.

Conversely, a complex system is aid to be non-stationary when dynamic changes in the parameters of the system result in a transition to a qualitatively different state. Systems whose parameters vary with time occur in many branches of science and engineering as well as the social and behavioral sciences.

4.2.3 REDUCTIONISM

Reductionism can either mean (a) an approach to understanding the nature of complex things by reducing them to the interactions of their parts, or to simpler or more fundamental things or (b) a philosophical position that a complex system is nothing but the sum of its parts, and that an account of it can be reduced to accounts of individual constituents.

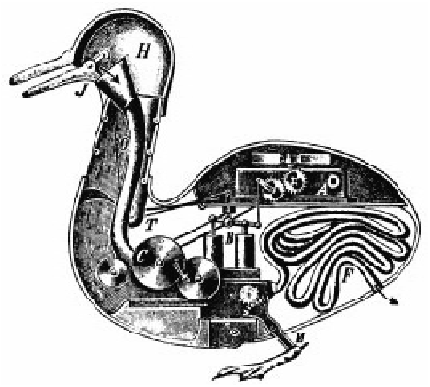

Figure 4.2: Descartes held the view that animals could be reductively explained as consisting of a series of gears and levers. (Credit: *De homines*, 1662)

A complex system cannot be described through a description of the individual parts or components. Such a system can only be understood in terms of the entire system and the interactions of all the various parts.

4.2.4 EQUILIBRIUM

Equilibrium is the condition of a system in which competing influences are balanced. Two kinds of equilibrium are referred to as stable and unstable. In a stable equilibrium condition, if the system is disturbed it moves back toward equilibrium condition while for the unstable equilibrium case, any disturbance results in movement away from equilibrium without the ability to recapture the original condition.

Complex systems behavior often is characterized by a sudden shift from one state to a totally different state and thus it is not helpful to even speak in terms of equilibrium for a complex system. Such systems are continuously evolving or more descriptively, evolving or unfolding from one state to a different state.

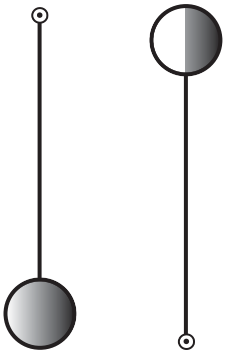

Figure 4.3: Stable and unstable equilibrium conditions for a pendulum.

4.2.5 PERTURBATION THEORY

Perturbation theory comprises mathematical methods that are used to find an approximate solution to a problem, which cannot be solved exactly, by starting from the exact solution of a related problem. Perturbation theory is applicable if the problem at hand can be formulated by adding a “small” term to the mathematical description of the exactly solvable problem.

Complex systems cannot be analyzed using perturbation theory as it is impossible to identify a “small “term rather it is impossible to predict the order of magnitude change that the system may display with the most infinitesimally small changes. Perhaps this may be best understood through a popular metaphor used in complex systems theory, the butterfly effect. The butterfly effect is a deceptively simple insight extracted from a complex modern field. In 1961, Lorenz created an early computer program to simulate weather. One day he changed one of a dozen numbers representing atmospheric conditions, from .506127 to .506. That tiny alteration utterly transformed his long-term forecast, a point Lorenz amplified in his 1972 paper, "Predictability: Does the Flap of a Butterfly's Wings in Brazil Set Off a Tornado in Texas?"[60] In the paper, Lorenz claimed the large effects of tiny atmospheric events pose both a practical problem, by limiting long-term weather forecasts, and a philosophical one, by preventing us from isolating specific causes of later conditions. The "innumerable" interconnections of nature, Lorenz noted, mean a butterfly's flap could cause a tornado - or, for all we know, could prevent one. Similarly, should we make even a tiny alteration to nature, "we shall never know what would have happened if we had not disturbed it," since subsequent changes are too complex and entangled to restore a previous state.

4.3 DESCRIBING COMPLEX SYSTEMS

Complex systems are networks of many components with nonlinear interactions, which arise and evolve through self-organization, such that the system is neither completely regular nor completely random, permitting the development of emergent behavior. These properties can be found in many real-world systems, e.g., gene regulatory networks in a cell, physiological systems, brains and other neural systems, food webs, stock markets, the Internet and social networking systems. We study their structural/dynamical properties to obtain general, cross-disciplinary implications and applications.

Complex Systems is a new field of science studying how parts of a system give rise to the collective behaviors of the system, and how the system interacts with its environment. Social systems formed (in part) out of people, the brain formed out of neurons, molecules formed out of atoms, and the weather formed out of air flows are all examples of complex systems. The field of complex systems cuts across all traditional disciplines of science, as well as engineering, management, and medicine. It focuses on certain questions about parts, wholes and relationships. These questions are relevant to all traditional fields.

The study of complex systems is about understanding indirect effects. Problems that are difficult to solve are often hard to understand because the causes and effects are not obviously related. Pushing on a complex system "here" often has effects "over there" because the parts are interdependent. This has become more and more apparent in our efforts to solve societal problems or avoid ecological disasters caused by our own actions. The field of complex systems provides a number of sophisticated tools, some of them concepts that help us think about these systems, some of them analytical for studying these systems in greater depth, and some of them computer based for describing, modeling or simulating these systems.

There are three interrelated approaches to the modern study of complex systems, (1) how interactions give rise to patterns of behavior, (2) understanding the ways of describing complex systems, and (3) the process of formation of complex systems through pattern formation and evolution.

Tools used to analyze complex systems are vey much different than those we are accustomed to use in our efforts to model linear phenomena. Several tools are presented in the present section as a brief introduction to the filed of complex systems science.

DAAWN (Detail as and When Needed)[61]

In complex systems, it is not possible to measure everything necessary to develop a predictive understanding of them. The Detail as and When Needed approach advocates an iterative and multi-scaled methodology in which the first goal is to capture as broad an understanding of the system as possible and then use the awareness developed at this scale to identify where to focus subsequent, more detailed, investigations. As it is not possible to measure or monitor everything in these complex and adaptive systems, the approach requires making judicious use of all available knowledge about the system. The DAAWN approach is rooted in systems theory, but is tempered by systems and problems where boundaries are not clearly defined, where nonlinearities are the norm, and where structural and functional change is the expectation.

CMACS (Computational Modeling and Analysis of Complex System)[62]

The aim of CMACS is to gain fundamental new insights into the emergent behavior of complex biological and embedded systems through the use of highly scalable and fully automated modeling and analysis techniques. It is a collaborative project between Carnegie Mellon University, City University of New York, New York University, Stony Brook University, University of Maryland, Cornell University, Jet Propulsion Laboratory, and University of Pittsburgh. The goals are to develop new computational tools to help scientists and engineers analyze and understand the behavior of the complex models they develop for application domains ranging from systems biology to embedded control. By combining and extending Model Checking and Abstract Interpretation, two well-established methods for automatically finding errors of digital circuit designs and embedded software, the project is expected to provide vital tools that will enable health-care researchers to discover better treatments for disease and will allow engineers to build safer aircraft, automobiles, and other complex systems.

WASPBED (A Complex Systems Based Tool for Collective Robot Behavior Emergence and Analysis)[63]

In WASPBED, a complex systems theory based methodology and tool for the automatic design of multi-agent or multi-robot collective behaviors for the optimized execution of a given task is developed. The main goal of this methodology is the representation of a generic task to be optimally performed in and the subsequent analysis of the emergent states thus obtained. This way, by tweaking environmental parameters in the system, the behaviors of the different collective behaviors obtained can be studied.

4.4 CONCLUDING THOUGHTS

This new area of research — fittingly called “complexity science” — embraces the notion that an ant colony and the human brain, the stock market and Facebook, all have something in common. All are complex systems, basically huge networks made up of individual components whose behavior is difficult to predict. A deeper understanding of these systems’ role in nature - and the emergence of computer science tools sophisticated enough to analyze them - offers scientists a more realistic framework for solving today's most vexing problems, from global warming to ethnic conflict.

The rise of complexity science is not driven by researchers, but actually from the complexity in people's lives according to practitioners in the field. Today networks and complex systems are everywhere, and there are several university-based centers and journals devoted exclusively to their study.

Complex systems are networks of many components with nonlinear interactions, which arise and evolve through self-organization, such that the system is neither completely regular nor completely random, permitting the development of emergent behavior. These properties can be found in many real-world systems, e.g., gene regulatory networks in a cell, physiological systems, brains and other neural systems, food webs, stock markets, the Internet, and social networking systems. We shall return to these properties – ***nonlinearity***, ***non-deterministic***, ***self-organization*** and ***emergent behavior*** – later when we attempt to integrate these ideas into a new engineering ethic.

CHAPTER 5

Quantum Mechanics

5.1 SUMMARY

In this next chapter, we consider some fascinating aspects of quantum mechanics including the ideas of connectedness, potentialities and the experience of an objective reality. We consider the implications of the famous thought experiment, Schrodinger's Cat. In addition, we compare a quantum world with the more familiar mechanical universe as outline by Newton and others from the Age of Science. Lastly, we consider a totally different way of conceptualizing light and postulate what might the consequences of such an interpretation be for us.

5.2 INTRODUCTION

Quantum mechanics makes some very significant observations about Nature, which may prove useful in developing a new engineering ethic. Many of these observations remain a mystery to many of us because they do not seem to fit into our view of the Universe as described by classical mechanics. The present chapter seeks to explain philosophical and practical implications of one of the several of the most important observations of quantum mechanics.

As a starting point, let us consider the following ideas offered by Feynman et al.[64]

> *"We have implied that in our experimental arrangement (or even in the best possible one) it would be impossible to predict exactly what would happen. We can only predict the odds! This would mean, if it were true, that physics has given up on the problem of trying to predict exactly what will happen in a definite circumstance. Yes! Physics has given up. We do not know how to predict what would happen in a given circumstance, and we believe now that it is impossible – that the only thing that can be predicted is the probability of different events. It must be recognized that this is a retrenchment in our earlier ideal of understanding nature. It may be a backward step, but no one has seen a way to avoid it... So at the present time we must limit ourselves to computing probabilities. We say "at the present time," but we suspect very strongly that it is something that will be with us forever – that it is impossible to beat that puzzle – that this is the way nature really is."*

Feynman continued:[65]

> *"A philosopher once said, 'It is necessary for the very existence of science that the same conditions always produce the same results. Well they don't!'"*

5.3 MIND OF A PARTICLE, MIND OF THE UNIVERSE

Let us consider the concept of mind. Several working definitions of mind are as follows:

> The human consciousness that originates in the brain and is manifested especially in thought, perception, emotion, will, memory, and imagination;
>
> The collective conscious and unconscious processes in a sentient organism that direct and influence mental and physical behavior;
>
> The principle of intelligence; the spirit of consciousness regarded as an aspect of reality; and
>
> The faculty of thinking, reasoning, and applying knowledge.

Let us ask what seemingly is the most elemental question of all and one that permeates popular philosophy of science discussions. Do particles have mind? According to Thakur:[66]

> "Mind is not a physical entity that can be defined through its physical or chemical properties. Like gravitational force, mind can only be defined through the effect it produces. Mind can only be defined as a non-physical entity that generates varied behaviors and varied responses by the entity in which it is located.
>
> There is no other way we can identify and define mind. When an entity produces predictable responses then we term the entity as 'mechanical.' Our own instinctive reactions are supposed to be mechanical; we do not get enough time to apply our mind to certain situations in which message does not even have time to reach the brain and in such situations we react instinctively and mechanically and therefore our responses are predictable. Application of mind is supposed to produce non-mechanical behavior. Going by this definition, we may say that particles do have mind."

Perhaps now we move to the next question, do particles make conscious decisions? Stated a different way Thakur[67] asks, "Do particles weigh the options available to them before they make a decision?" That is a question which beyond our knowledge at the present time and is considered outside the realm of scientific inquiry. One might ask, how can I ever know what is inside the mind of a particle when I cannot know what is in the mind of a closest friend or even my own mind on too many occasions!

Placing the discussion of particle choices in a more scientific context, one of the most remarkable features of this projection is that the actual event, which manifests in any given case is determined only by probability. When the state becomes active, there is a sudden, discontinuous jump in the state that has an element of true spontaneity to it. Although deterministic laws still apply to the unobserved potentials, the result is free and spontaneous. It is not determined by the particular circumstances surrounding the event but is truly spontaneous. What manifests upon observation is not determined—even in principle.

Thus, in the quantum realm, the deterministic machine has broken down. No longer is the Universe a giant cosmic machine, predetermined with no room for spontaneity. While there is a deterministic law in the quantum realm, it has limitations, applying only to the possibilities while we are not looking. When we look, however, the potential is made actual, breaking deterministic law and introducing spontaneity into the world. There is no predicting which state will become active—only the probabilities are determined. The cosmic machine is falling apart, its matter dissolving into potentiality, its determinism making room for freedom.

5.4 MECHANICAL UNIVERSE VS. QUANTUM WORLD

In Newton's mechanistic universe, not only was reality made of matter, which followed strict deterministic law, but also it is thought to be composed of many separate, independent material particles. The question to explore next asks: Is the quantum world, like the classical world, composed of separate, independently existing entities or is it one entity? In other words, is this new world of potentiality made up of multiple universes or only one Universe?

Consider the following thought experiment:[68]

> "Let us, for the sake of simplicity, consider a system of just two particles which have interacted with each other at some point in the past. Suppose we have a box as and each particle can be either in the box or out of the box. Now when we look, we will find one of four actual states: (1) both in the box, (2) both out of the box, (3) one in the box and the other out of it, and (4) vice versa. So our possibility space for the system will have four directions, and a single state vector pointing in some combination of the four directions will represent the state of this two-particle system. For example, if the vector has a large component in the direction where both particles are in the box, then the probability of finding the particles in that actual state will be large. But, so long as the vector has components in the other directions as well, there is a possibility of finding one of several actual states when we look. Thus, the state vector represents a potential for the particles to be found in any of the four possible states we can actually observe.
>
> Now it is important to notice that the one state vector describes the potentialities of both particles. So if you look at one of the particles, the state vector for the whole system will be projected. Thus, by looking at one of the particles, you have determined what is 'real' for both of them. For example, if you find one particle in the box, then the other

> particle will be either actually in the box or actually out of the box, and not potentially in or out of the box. When one particle becomes active, both become active.
>
> What is amazing about this is that the other particle becomes active instantly—even if it is in another galaxy. One might think at first that some strange faster-than-light communication is necessary to coordinate the two particles. But such strange mechanisms are not at all necessary when we remember that the two particles were not really separate in the first place—the one state vector described the potentiality for them both. Thus, in the world of potentiality, there were not two particles at all, but just one potentiality, which contained the possibilities for the manifestation of them both. And, since the potentiality exists in a possibility space and not in physical space, the "actual" distance between the particles is irrelevant. Although they are separated when manifested in space-time, in the potential world beyond space-time they are united as one. Thus, the complementary wave-particle aspects of matter are accompanied by their respective nonlocal-local aspects."

The implications of this experiment are profound. In this quantum world, all things are interconnected far beyond the limits of space and time. Two particles whether they exist within sub-microns of each other or are separated by billions of light years are connected and united in one wave of potentiality. While the world appears to be a Many, quantum mechanics demonstrates that it is fundamentally a One.

Another important question that quantum mechanics asks is whether or not an observer affects the result of the experiment? This leads to the famous Schrodinger Cat paradox.

A cat, along with a flask containing a poison and a radioactive source, is placed in a sealed box shielded against environmentally induced quantum de-coherence. If an internal Geiger counter detects radiation, the flask is shattered, releasing the poison that kills the cat. The Copenhagen interpretation of quantum mechanics implies that after a while, the cat is simultaneously alive and dead. Yet, when we look in the box, we see the cat either alive or dead, not both alive and dead.

The Copenhagen Interpretation[69] says that in the Schrödinger's cat experiment in which the perception of the history of the outcome of the cat (whether the cat is dead or alive) is decided at the moment in which the observer collapses the wave function (opens the box and watches the cat). By doing that the observer is *creating the perception* of the previous history of the cat (whether the cat is death or alive) even though there is no objective thing as a cat.

The Copenhagen Interpretation[70] does not claim that an "objective history" is created through the act of observation. It claims that "there is no objective history" because there is no distinct (separable) objective reality. Reality is best described, at its basic level, in relation to our experience of it.

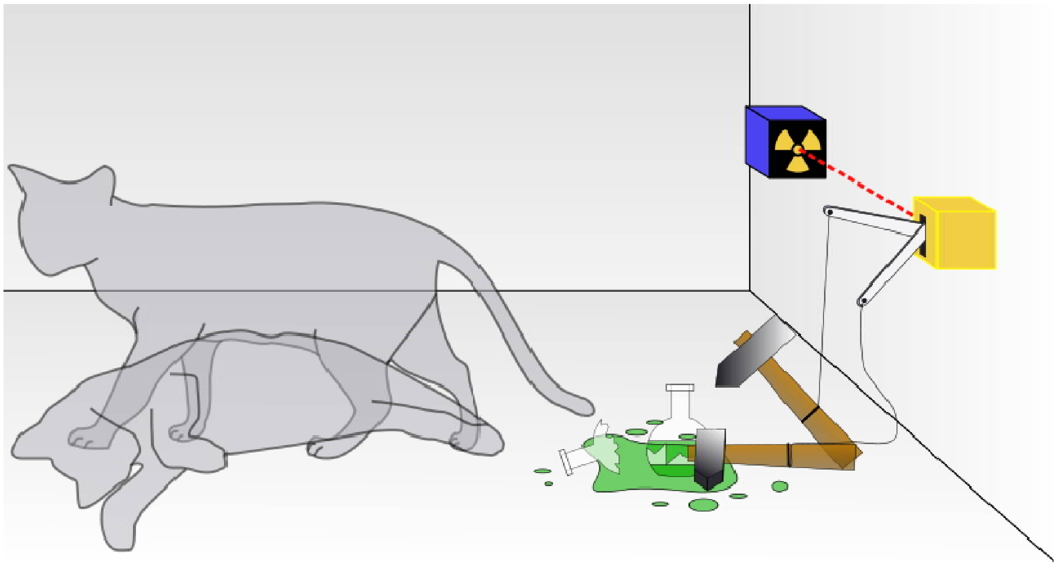

Figure 5.1: Schrodinger's Cat. (Credit: Creative License)

5.5 CONCLUDING THOUGHTS

Perhaps no example more simply describes the difference between imagining the Universe as a mechanical device versus insights from a quantum world than does the physics of light impinging upon a solid surface. Whether we first saw the diagrams on high school or college, we have all encountered the ray drawings as described by Snell's law. In optics and in physics, Snell's law is a formula used to describe the relationship between the angles of incidence and refraction, when referring to light or other waves passing through a boundary between two different isotropic media, such as water and glass. The law says that the ratio of the sines of the angles of incidence and of refraction is a constant that depends on the media. The refractive index can be calculated by rearranging the formula accordingly.

Snell's Law describes the relationship between the angles and the velocities of the waves. Snell's law equates the ratio of material velocities V_{L_1} and V_{L_2} to the ratio of the sines of incident (Θ_1) and refracted (Θ_2) angles, as shown in the following equation:

$$\frac{\mathrm{Sin}[\Theta_1]}{V_{L_1}} = \frac{\mathrm{Sin}[\Theta_2]}{V_{L_2}}$$

where V_{L_1} is the longitudinal wave velocity in material 1 and V_{L_2} is the longitudinal wave velocity in material 2.

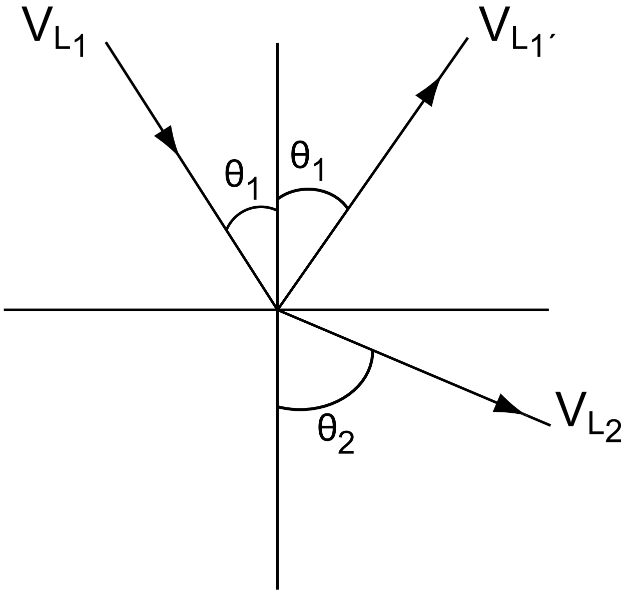

Figure 5.2: Schematic Drawing of Snell's Law.

From a mechanical world perspective, this all seems to make perfect sense. A light photon travels along its path, caroming much like a billiard ball on a billiards table. There is nothing very unusual happening here! However, we have learned that if we consider the same phenomenon from a quantum perspective, it is no longer the same photon after impact.

What might the implications of this different model be? How is our conception of the world different if rather than having caroming photons, we have, in fact, first an acceptance and then a giving forth of the packet of energy? I would suggest it is a very different place than the cold, impersonal world of billiard balls, and mechanical contrivances. There is the notion of connectedness, surely, as one photon packet is accepted into a new community. Then rather than simply accepting the addition light energy, there is, in turn, a giving back at a different place and different time.

CHAPTER 6

Evolving Principles of the Universe

6.1 SUMMARY

Berry set forth what he termed the New Story for our understanding of the evolution of the Universe and our place and role in that evolving process. As part of that model, Berry[71] and Swimme and Berry[72], identified three basic laws of the Universe at all levels of reality, which are differentiation, subjectivity, and communion. These laws identify the reality, the values, and the directions in which the Universe is proceeding.

In this next chapter in the present work, we shall explore the implications of each of the three basic laws and apply these laws to a wide range of scenarios including family gatherings, engineering design teams, simple co-systems and a native society embedded in a larger nation.

6.2 INTRODUCTION

Our new understanding of the processes of the Universe has been described in Berry's New Story. Berry has derived from Teilhard[12] an enormous appreciation for developmental time and from Darwin's[13] *Origin of Species*[73] an awareness of the universe not simply as a static cosmos but as an unfolding cosmogenesis. The theory of evolution provides a distinctive realization of change and development in the universe, which positions us in a huge sweep of geological time.

In the New Story, Berry has also derived an understanding of the psychic-physical character of the unfolding universe. This implies that if there is consciousness in the human and if humans have evolved from Earth, then from the beginning some form of consciousness or interiority is present in the process of evolution. Matter is not simply dead or inert, but a numinous reality consisting of both a physical and spiritual dimension. Consciousness, then, is an intrinsic part of reality and is the thread that links all life forms. There are various forms of consciousness and, in the human, self-consciousness or reflective thought arises.

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[12] Pierre Teilhard de Chardin SJ was a French philosopher and Jesuit priest who trained as a paleontologist and geologist and took part in the discovery of both Piltdown Man and Peking Man. Teilhard's primary book, The Phenomenon of Man, set forth a sweeping account of the unfolding of the cosmos. He abandoned traditional interpretations of creation in the Book of Genesis in favor of a less strict interpretation.

[13] Charles Robert Darwin was an English naturalist. He established that all species of life have descended over time from common ancestry, and proposed the scientific theory that this branching pattern of evolution resulted from a process that he called natural selection. He published his theory with compelling evidence for evolution in his 1859 book *On the Origin of Species*. In modified form, Darwin's scientific discovery is the unifying theory of the life sciences, explaining the diversity of life.

Berry also suggests that as things evolve from simpler to more complex organisms, consciousness also increases. Ultimately self consciousness or reflection emerges in the human order. The human as a highly complex mammal is distinguished by this capacity for reflection. This gives humans a special role in the evolutionary process. We are part of not apart from Earth.

6.3 LAWS OF THE EVOLVING UNIVERSE

The laws of the Universe as described in the *New Story* are the following:

I. Law of Differentiation

II. Law of Subjectivity

III. Law of Communion

6.3.1 DIFFERENTIATION

> *"The beginning of the Universe was not a homogeneous smudge but rather involved articulated energy constellations bound together in an inseparable unity."*
>
> *Thomas Berry.*

The biodiversity found on Earth today consists of many millions of distinct biological species. Biodiversity herein is the variation of life forms within a given ecosystem, biome, or for the entire Earth. Differentiation is a term often used in system theory. For example, from the viewpoint of this theory, the principal feature of modern society is the increased process of system differentiation as a way of dealing with the complexity of its environment. A consideration of the evolution of the Universe points to the fact that the Universe is characterized by relentless emergent diversification from particles to life forms. Helium and hydrogen gases present immediately after the Big Bang yielded to more complex particles, then on to stars, solar systems and planets, which eventually led to the appearance of life on Earth. Life on Earth then proceeded from the most basic forms of life, prokaryotic and eukaryotic cells, to the biodiversity that we can observe on our planet today.

Formally, biodiversity is the variation of life forms within a given ecosystem, biome, or for the entire Earth. The biodiversity found on Earth today consists of many millions of distinct biological species.

The essence of the movement of the Universe towards differentiation is aptly described the following quote[74]:

> *"This is the greatest discovery of the scientific enterprise: You take hydrogen gas, and you leave it alone, and it turns into rosebushes, giraffes, and humans."*
>
> *Brian Swimme.*

Figure 6.1: Rich diversity of species near coral reef in the Caribbean. (Credit: U.S. Environmental Protection Agency)

What, we may ask, are the implications of the law of differentiation? Clearly, the Universe prefers an infinitely varying solution for present day existence. We have moved as Swimme[75] states from hydrogen gas to the infinite varieties of plant, and animal life forms here on Earth as well as an infinite variety of astronomical and sub-atomic bodies spread throughout the Universe. This is reminiscent of the Second Law of Thermodynamics[14], which indicates processes proceed in a manner in which disorder increases.

---

[14] 2nd Law of Thermodynamics. The simplest statement of the 2nd law is that the entropy of the Universe tends towards a maximum. In terms of time variation, the mathematical statement of the 2nd Law for an isolated system undergoing an arbitrary transformation is:

$$\frac{dS}{dt} \geq 0$$

where S is the entropy and t is time.

Table 6.1: Rates of extinctions from 1996–2004. Source: 2004 Red List of Threatened Species.[76]

Rate of extinctions in recent years

	Number of described species	Number of species evaluated in 2004	Number of threatened species in 1996	Number of threatened species in 2000	Number of threatened species in 2002	Number of threatened species in 2003	Number of threatened species in 2004	Number threatened 2004, as % of species described
Vertebrates								
Mammals	5,416	4,853	1,096	1,130	1,137	1,130	1,101	20%
Birds	9,917	9,917	1,107	1,183	1,192	1,194	1,213	12%
Reptiles	8,163	499	253	296	293	293	304	4%
Amphibians	5,743	5,743	124	146	157	157	1,770	31%
Fishes	28,500	1,721	734	752	742	750	800	3%
Subtotal	**57,739**	**22,733**	**3,314**	**3,507**	**3,521**	**3,524**	**5,188**	**9%**
Invertebrates								
Insects	950,000	771	537	555	557	553	559	0.06%
Mollusks	70,000	2,163	920	938	939	967	974	1%
Crustaceans	40,000	498	407	408	409	409	429	1%
Others	130,200	55	27	27	27	30	30	0.02%
Subtotal	**1,190,200**	**3,487**	**1,891**	**1,928**	**1,932**	**1,959**	**1,992**	**0.17%**

Source: 2004 Red List of Threatened Species[lxxvi]

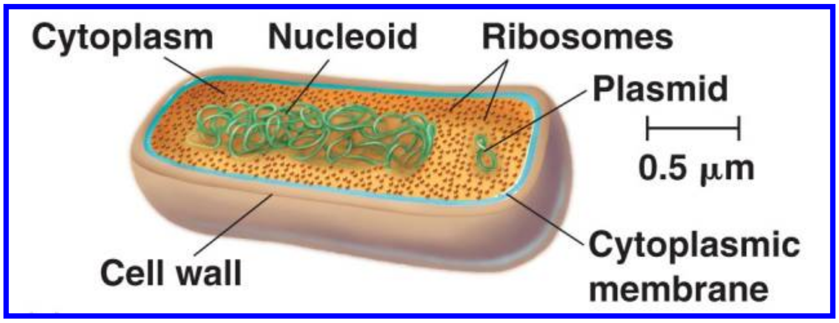

Figure 6.2: Cell structure of prokaryotic life.

Figure 6.3: Example of smallest known eukaryotic cell with an estimated diameter of 0.8 microns. (Credit: Entangled Bank, Dr. Paul's Virtually Biology Show, `www.plosbiology.org`)

6.3.2 SUBJECTIVITY

> *"Every particle has its identifying inner structure, its inner being. In a sense everything participates 'in person,' as it were, everything has its voice."*
>
> *Thomas Berry.*

Subjectivity may refer to the specific discerning interpretations of any aspect of experiences. They are unique to the person experiencing them, and are only available to that person's consciousness.

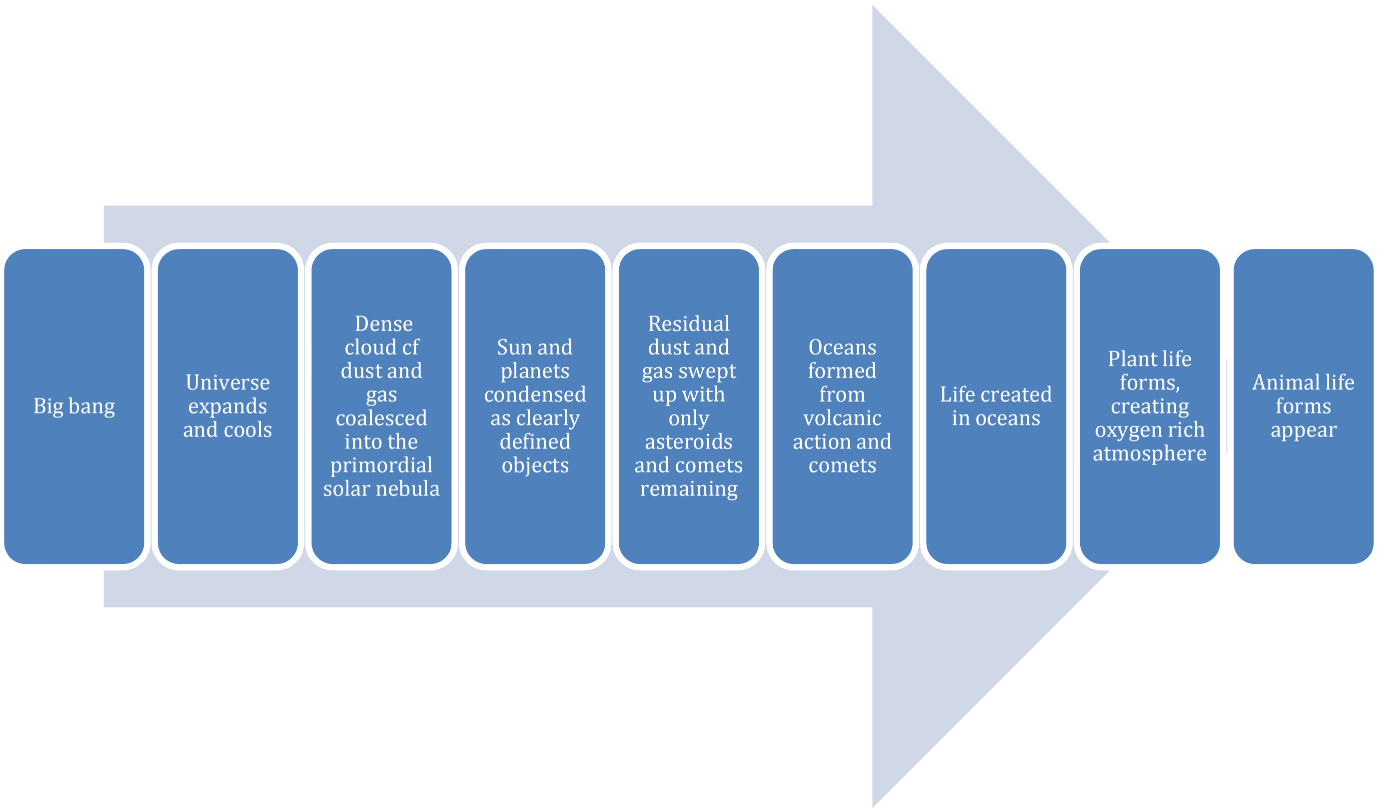

Figure 6.4: Differentiation in the Evolving Universe.

Table 6.2: Changes in percentage of land used for agriculture. Source: International Institute for Environment and Development/World Resources Institute.[77]

Area of agricultural land by region (1900–1980) in sq km			
	1900	**1980**	**% change**
North America	1,330,000	2,030,000	+53
Latin America	330,000	1,420,000	+330
Europe	1,450,000	1,370,000	-5
Former USSR	1,470,000	2,330,000	+58
Sub-Saharan Africa	730,000	2,220,000	+204
South Asia	890,000	2,100,000	+136
South-East Asia	150,000	550,000	+267
China	890,000	1,340,000	+51

Source: International Institute for Environment and Development/World Resources Institute[lxxvii]

The concept of subjectivity forces us to ask the question who actually matters rather than the more familiar what matters? If one asks who matters, then the Universe itself is not a collection of objects but something much different. We are used to separating our world into subjects that act and objects that are acted upon. Often we are the only ones who allow ourselves to assume the roles of subjects with the rest of the Universe only permitted to react to our actions and thus destined to be objects.

Berry[78] offered the following interpretation of subjectivity:

> *"Every particle has its identifying inner structure, its inner being. In a sense everything participates 'in person,' as it were, everything has its voice."*

If we allow the rest of the Universe to have a voice, what might we begin to hear spoken from whom that we have never heard before?

What is demanded from us in the shifting from a Universe filled with objects to one with subjects? That which is demanded is what Regan[15] refers to as the "Thee Generation."[79] The movement embedded within this generation is a revolution of the human spirit. In this revolution, Regan contends that the expansive ethic of service replaces the suffocating ethic of greed. Unlike previous generations, "The Thee Generation" asks, "What do I have to give?" rather than "What can I get to keep?" Regan defines "Thee" as those to be served: the handicapped, the poor, the

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[15] Tom Regan is an American philosopher who specializes in animal rights theory. He is professor emeritus of philosophy at North Carolina State University, where he taught from 1967 until his retirement in 2001. Regan is the author of numerous books on the philosophy of animal rights, including ***The Case for Animal Rights***. In these, he argues that non-human animals are what he calls the "subjects-of-a-life," just as humans are, and that, if we want to ascribe value to all human beings regardless of their ability to be rational agents, then to be consistent, we must similarly ascribe it to non-humans.

Figure 6.5: Alpine ecosystem.

illiterate, the homeless, the starving and the abused, those newly born, and those soon to die. This generation is generous enough to include the animal kingdom, and even the Earth itself, for the world of "The Thee Generation" is a place where a shared sense of community replaces the void of individual estrangement.

The questions raised by this revolution force us to consider the boundaries of the moral community, and what it means to be human in our own generation: "The human is but one life form among many, and what distinguishes us from the larger community of life is not our power to subdue but our responsibility to protect."[80]

6.3.3 COMMUNION

> *"Everything speaks itself and everything is receiving something from every other particle in the Universe. Every atom in the Universe is immediately influencing every other atom in the Universe, no matter how distant, even if it is billions of light years away."*
>
> *Thomas Berry.*

Communion is an exchange of thoughts, emotions, etc., or a possession or sharing in common. It is often accompanied by strong emotional or spiritual feelings as, for example, in communion with nature.

Figure 6.6: Spiral Galaxy. (Credit: NASA)

Thomas Berry has written:

> *"The Universe is a communion of subjects, not a collection of objects."* (sic. And every subject is different! There are no repeats!)[81]

Berry further adds that

> "Everything speaks itself and everything is receiving something from every other particle in the Universe. Every atom in the Universe is immediately influencing every other atom in the Universe, no matter how distant, even if it is billions of light years away."[82]

6.4 FRACTAL NATURE OF THE EVOLVING LAWS

A visual representation of the interconnectedness of the three laws is shown in Figure 6.6. Each law separately is depicted as a triangle and each vertex of each triangle has a unique interpretation. Common vertices indicate the presence of two of the laws. The differentiation triangle shares one vertex with subjectivity and one vertex with communion. Similarly, the subjectivity triangle shares one vertex with differentiation and one vertex with communion. Lastly, the communion triangle shares one vertex with differentiation and one vertex with subjectivity.

The innermost triangular shape has the following three shared vertices: (1) subjectivity and communion, (2) differentiation and communion, and (3) differentiation and subjectivity. The area within the inner triangle then can be seen to represent the union of all three laws.

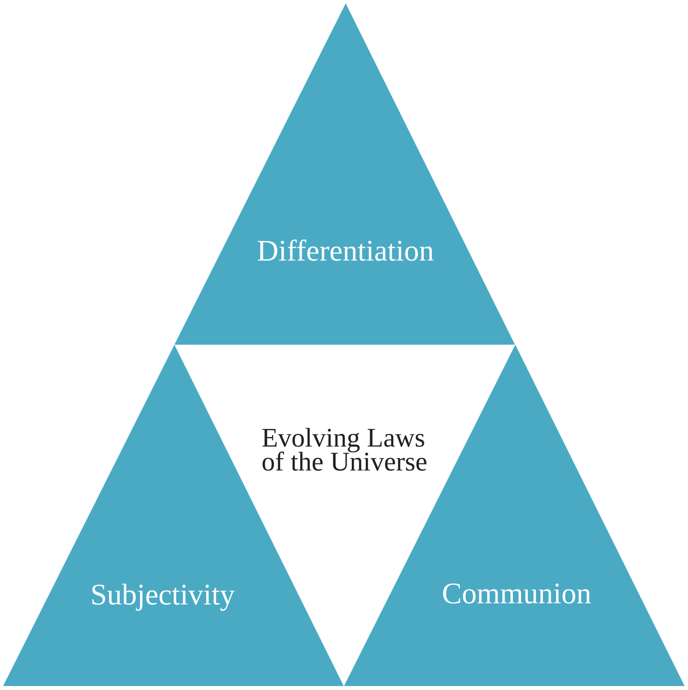

Figure 6.7: Laws of the Unfolding Universe.

We could further refine the fractal shape as well. Each of the original three separate fractal triangles could be subdivided in a similar manner. Suppose we consider the subjectivity shape as our starting point. (Figure 6.7). The vertices for this fractal triangle are the following: (1) subjectivity, (2) differentiation and subjectivity, and (3) communion and subjectivity. For this Universe, all the of the governing laws are indeed present, yet there will be a slightly increased emphasis on the value of the individual members of the community

Next, suppose we consider the communion shape as our starting point. (Figure 6.8). The vertices for this fractal triangle are the following: (1) communion, (2) differentiation and subjectivity, and (3) subjectivity. For this Universe, all the of the governing laws are indeed present, yet there will be a slightly increased emphasis on the value of the individual members and their uniqueness within the community.

Lastly, let us consider the subjectivity shape as our starting point. (Figure 6.9). The vertices for this fractal triangle are the following: (1) subjectivity, (2) differentiation and subjectivity, and

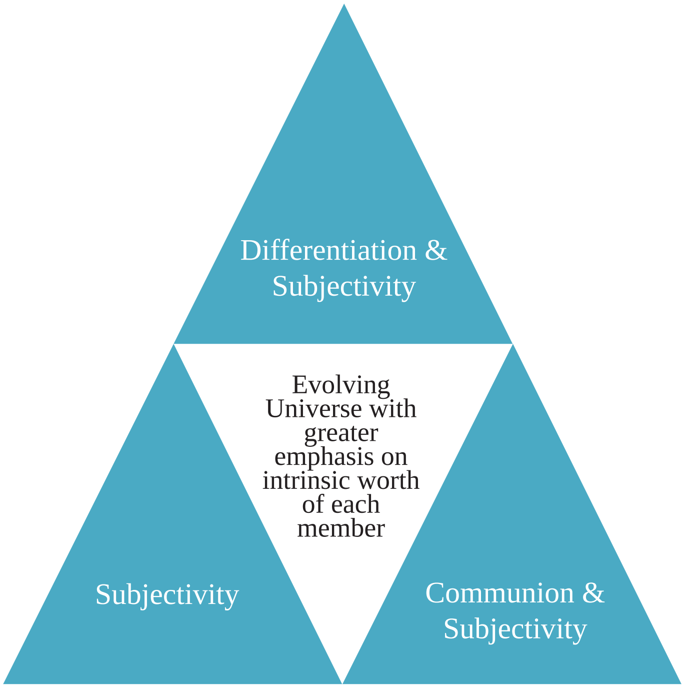

Figure 6.8: Evolving Universe with Greater Emphasis on Intrinsic value of all members.

(3) communion and subjectivity. For this Universe, all the of the governing laws are indeed present, yet there will be a slightly increased emphasis on the value of the individual members of the community.

6.5 INTEGRATION OF THE LAWS AND APPLICATIONS

To gain insight into the implications of the three laws, we shall consider several simple examples including a family gathering, an engineering design team, a simple ecosystem, and a Native American nation embedded in the United States. We shall ask in each case what will be the consequences of abandoning one of the three principles with the other two remaining?

6.5.1 FAMILY GATHERINGS

In order to explore the significance of the three fundamental principles of the evolving Universe let us first bring the discussion closer to home. Consider the following scenario. You are sitting around the family dinner table—feel free to select your family of origin or your family of choice! Imagine the scene that unfolds. Thinking back to Sundays around my family table, the television would be set to the local bowling show, followed by the New York Giants football game. My father would no doubt

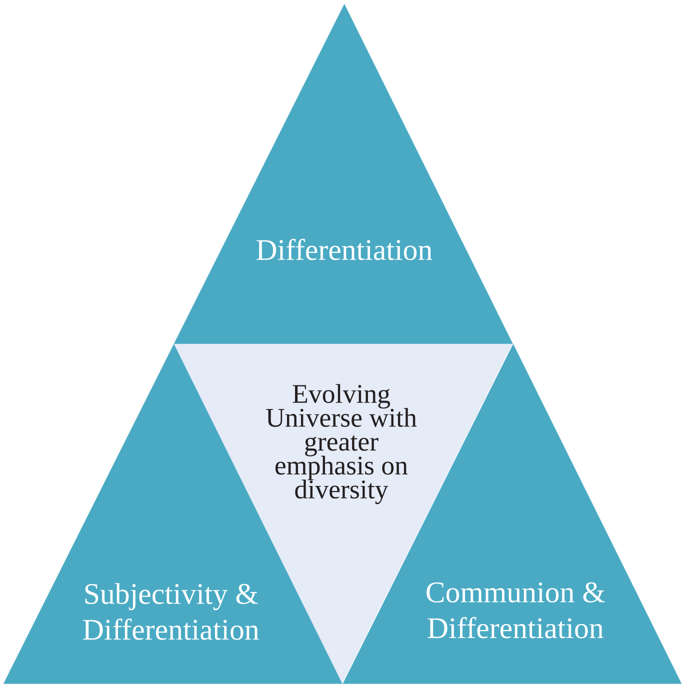

Figure 6.9: Evolving Universe with greater emphasis on diversity.

be talking about how bad the Giants were that year, and the increasing tensions associated with the local machinists' union strike against one of the city's major corporations. My mother would be busy cooking, cleaning and talking about a host of issues with my sister or calling my grandmother on the telephone to insure that she was going to visit us. I would try to insert myself in the various conversations though I never seemed to be very effective at coming up with important things to say. I often turned and talked softly to my dog. This scene like countless other gatherings at the dinner table throughout the world has the three principles present: we certainly are all very different, we certainly believe that each of us has a self that matters and we also believe that we are a family unit.

Suppose at that same dinner table only two out of the three principles were present.

Case 1: Subjectivity + Communion only

Let us start first without differentiation but still with subjectivity and communion. We would still feel that we each mattered and that we belonged to something bigger than ourselves individually but eventually we would all become exactly the same. We would think the same, act the same, say the same things, have the same interests and the list could go on ad infinitum. Whatever interests we did have in the outside world would disappear as in fact there would be no distinction between

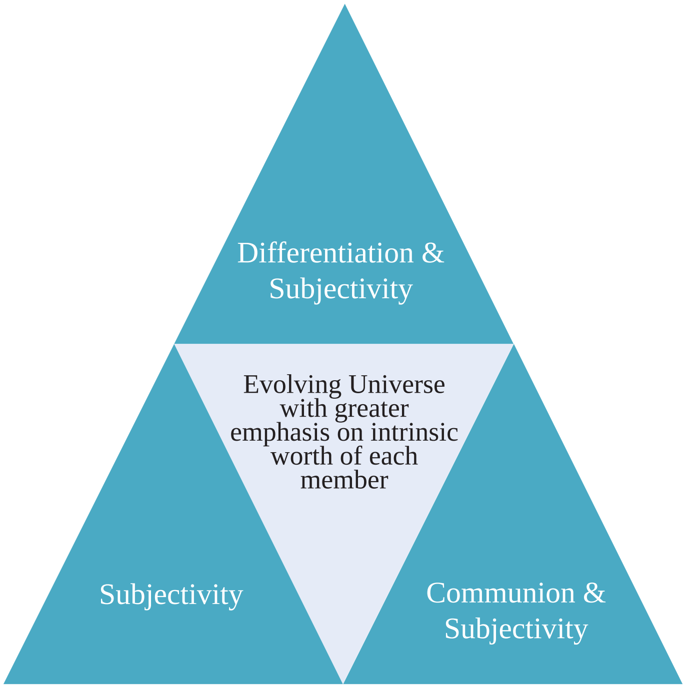

Figure 6.10: Unfolding Universe with greater emphasis upon intrinsic worth of each member.

that outside world and us. This world sounds frightfully boring. One cannot help but wonder how a new creative idea might arise?

Case 2: Differentiation + Communion only

Suppose now that family scene has differentiation and communion but no subjectivity. We would initially be different and still feel a part of something but we would soon become lost in the lives of everyone else. Perhaps it would be the ultimate example of a whole society filled with enabling personalities. One cannot help but wonder how things might ever change or how things might ever improve for the good. We would spend our whole days making sure that everyone else received exactly what he or she wanted without a hint of a challenge. How might any of us grow in wisdom?

Case 3: Differentiation + Subjectivity only

Lastly, our family has differentiation and subjectivity but no communion. We are each very different and each has a very definite sense of self, yet we feel absolutely no connection to the other members of our family or to society as a whole. It truly does become then all about me. The rest of the world has no value other than in helping me reach my goals or in feeling satisfied with my life. It is a world characterized by competition at all costs because no one else ultimately matters in the end.

6.5.2 ENGINEERING DESIGN TEAMS

Let us next consider the effectiveness of an engineering design team. As was done for the case of a family gathering, we shall consider three scenarios: subjectivity and communion, differentiation and communion, and differentiation and subjectivity.

Case 1: Subjectivity + Communion only

Our design each feels a sense of self and a sense of commitment to the other members of the team but cannot differentiate themselves from the other members. The attitudes, thoughts and feelings are identical. The individual team members cannot feed off the ideas of others because they, in fact, are exactly alike. There does not seem much hope here for an original thought or a moment of inspiration.

Case 2: Differentiation + Communion

In this case, the individual members are each different; they have the ability to identify those differences. They also have a sense of belonging to a team. That which is absent is the ability to express one's own thoughts, feelings and perspectives. Those voices become submerged and are lost to expression. Each member cannot identify his or her own unique gifts that can be given to the deliberations.

Case 3: Differentiation + Subjectivity

Here, the individual team members clearly are different and can identify those differences and express them. That which is lacking is the sense of belonging to a greater unit or system. In fact, there is no notion of doing what is in the best interest of the system as whole, so progress can only be identified in terms of what is good for the individual.

6.5.3 A SIMPLE ECOSYSTEM

Let us consider a simple single species predator-prey ecosystem. One of the most studied systems is the wolf-moose dynamic in Isle Royale located within Lake Superior. The island is 45 miles (72 km) long and 9 miles (14 km) wide, with an area of 206.73 square miles (535.43 km2), making it the largest natural island in Lake Superior, the second largest island in the Great Lakes after Manitoulin Island, the third largest in the contiguous United States (after Long Island and Padre Island), and the 32nd largest island in the United States. As of the 2000 census, there was no permanent population.

Let us focus on the wolves in Isle Royale and examine what may happen if the different laws of the Universe are not in place.

Case 1: Subjectivity + Communion only

Each member of each species has a sense of self and also a sense of belonging to something beyond itself but the distinctions between the wolves disappear. There are no alpha wolves, no omega wolves, nor are their aunt and uncle wolves who will take care of the packs when the adults are away on a hunt. Soon thereafter, the wolves will lose their differentiation from the moose who also inhabit the island. They [wolves] will likely become more like moose and moose more like them.

Case 2: Differentiation + Communion

In this case, the individual members of the species are each different; they have the ability to identify those differences. They also have a sense of belonging to a pack. That which is absent is a sense of self awareness and self-importance as well as awareness of the importance of the different roles in the pack or the value even of young pups.

Case 3: Differentiation + Subjectivity

Here, the individual team members clearly are different and can identify those differences and express them. That which is lacking is the sense of belonging to a greater unit or system. In fact, there is no notion of doing what is in the best interest of the system as whole, so progress can only be identified in terms of what is good for the individual. The pack structure will soon quickly deteriorate and the myth of the lone wolf will become a reality.

6.5.4 A NATIVE AMERICAN NATION IN LARGER UNITED STATES

The Onondaga Nation is a member of what is now commonly referred to as the Haudenosaunee (a name translated as the "People of the Long House"), an alliance of native nations united for the past several hundred years by complementary traditions, beliefs and cultural values. Sometimes referred to as the Iroquois Confederacy or Six Nations, the Haudenosaunee originally consisted of the Mohawk, Oneida, Onondaga, Cayuga, and Seneca nations. The Tuscarora migrated from the south and peacefully joined the Confederacy in the early 1700's, bringing to six the number of nations united by Haudenosaunee traditional law.

Like other member-nations of the Haudenosaunee, the Onondaga Nation survives today as a sovereign, independent nation, living on a portion of its ancestral territory and maintaining its own distinct laws, language, customs, and culture. Today, the Onondaga Nation consists of a 7,300-acre territory just south of Syracuse, on which it maintains its sovereignty and operates outside the general jurisdiction of New York State. The Nation is still governed by a Council of Chiefs, selected in accordance with its time-honored democratic system. In the same vein, many Onondagas practice traditional ceremonies and adhere to religious philosophies and social customs that long predate contact with Western civilizations. Aspects of this ideology have been incorporated into America's legal system, as well as into its culture. Personal and societal consideration of the Seventh Generation is but one example of a Haudenosaunee world view that has informed, enhanced and enlightened American and other national cultures.

Case 1: Subjectivity + Communion only

Our native society each feels a sense of self and a sense of commitment to the other members of the team but cannot differentiate themselves from the other members. The attitudes, thoughts and feelings are identical. There are no elders, no shamans, and no teachers. Soon the notion of a unique culture will also ebb as the Native culture and the surrounding U.S. culture will blend into one indistinguishable culture with the vast and overwhelming numbers of the U.S, society totally erasing the uniqueness of the Native Americans.

Case 2: Differentiation + Communion

In this case, the individual members are each different; they have the ability to identify those differences. They also have a sense of belonging to the native society. That which is absent is the ability to express one's own thoughts, feelings and perspectives. Those voices become submerged and are lost to expression. Each member cannot identify his or her own unique gifts that can be given to the deliberations.

Case 3: Differentiation + Subjectivity

Here, the individual native members clearly are different and can identify those differences and express them. That which is lacking is the sense of belonging to a greater unit or system or clan as it is referred to by the Onondaga. In fact, there is no notion of doing what is in the best interest of the clan as progress can only be identified in terms of what is good for the individual.

6.6 CONCLUDING THOUGHTS

Much of the environmental movement, at least in the West, has been based on the science of centuries ago, a science which models the Universe as nothing more than a collection of parts, albeit a very complicated one, but ultimately a machine. The mechanical universe then does many things. It removes us from being a part of it as we certainly are much more than a "machine." It also helps us develop the idea that we can somehow manage this machine and even more than that, fine tune it so that it does for us what we want it to do. There are the strong underpinnings of management and control. There also exists an implication that cause leads to effect, and it will be the effect we want as long as we are careful and clever in prescribing the proper causes.

The *New Story* represents some of the most current ideas in eco-philosophy. We have replaced the mechanical universe metaphor for an unfolding process of which we are integrally a part. This *New Story* offers us three fundamental laws: differentiation, subjectivity and communion. We shall return to these laws in the next chapter along with the insights offered from quantum mechanics and complex systems in our effort to create a new engineering ethic.

CHAPTER 7

A New Engineering Ethic

7.1 SUMMARY

We shall propose a new engineering ethic. Explorations of the significant concepts and principles as outlined in the theories of complex systems, quantum mechanics and in the laws of the unfolding universe point to a consistency and unity of thought evidenced in each of these very distinct and disparate disciplines. Brought together, all of these ideas point to a very different understanding of our world and, ultimately, our place in it then has existed previously, and as a result, a profoundly different sense of ethical responsibility for our profession.

7.2 A UNION OF IDEAS: COMPLEX SYSTEMS, QUANTUM MECHANICS AND THE UNFOLDING UNIVERSE

From complex systems, we learned that our world is one characterized by non-linearity, self-organization and emergence. From quantum mechanics, we learned to forgo the mechanical universe mindset and allow for a vast array of potentialities rather than limited certainties, that the elements in the Universe have what we termed in effect "minds" have and the understanding that reality does not exist apart for our experience of it. From the theory of an unfolding Universe, we learned that the Universe is governed by a set of three principles – the principles of differentiation, of subjectivity and of communion.

7.3 A NEW ENGINEERING ETHIC

Earlier in this work, reference was made to the NSPE code of ethics[83] which states:

> *Engineers, in the fulfillment of their professional duties, shall hold paramount the safety, health, and welfare of the* ***public****.*

That same structure will be incorporated into the present work. A new engineering ethic can now be formulated:

Engineers, in the fulfillment of their professional duties, shall

> *Recognize the Universe as being filled with infinite potentialities and that decisions that limit the various life-forms from reaching their unique potentials must be carefully considered;*

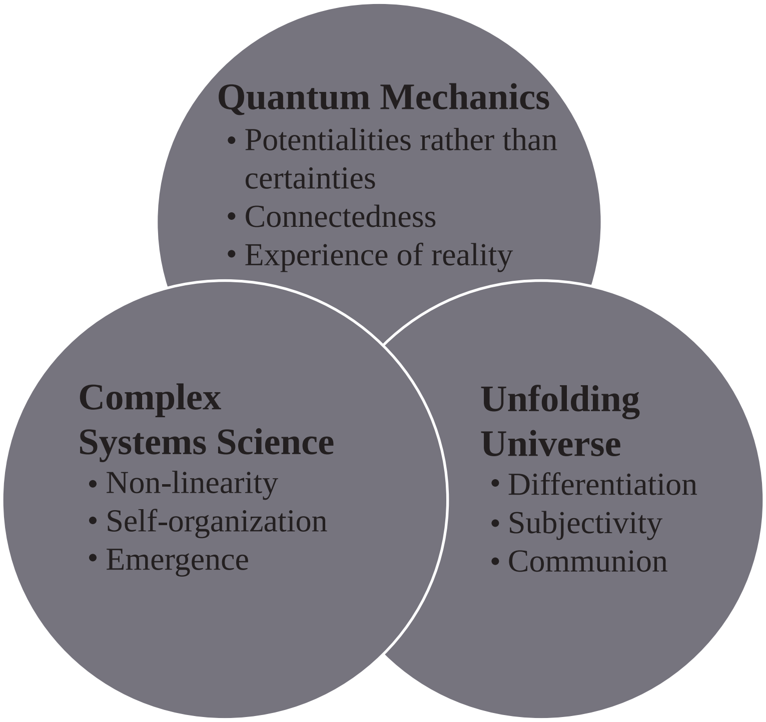

Figure 7.1: Union of Ideas from Quantum Mechanics, Complex Systems and the Unfolding Universe.

> *Recognize the Universe as complete and connected throughout;*
>
> *Be cognizant of the various filters through which each of us experiences what we claim to be our reality;*
>
> *Forgo the notion of linearity and its attendant principle of superposition, that is, the whole being simply the sum of its parts;*
>
> *Understand that a totally unexpected result may emerge from systems no matter how carefully and tightly controlled the systems and the inputs might seem;*
>
> *Recognize that various elements in a system may have desire to organize themselves in ways that cannot be anticipated form the outside;*
>
> *Promote diversity rather than seek to reduce differentiation and move towards homogenization;*
>
> *Recognize the intrinsic value of all life forms rather than seek to establish a hierarchy of life forms both across and within species; and*

Nurture the sense of a community rather than seek to destroy those communities, societies or cultures.

Conversely, an unethical act would:

Recognize the Universe as being filled with infinite potentialities and that decisions that limit the various life-forms from reaching their unique potentials must be carefully considered;

Model the universe as collection of gears and lever, pieces and parts, each of which can be changed so that the machinery of the universe can be fine-tuned much as the tuning of a watch or automobile;

Maintain that there exists an historical objective reality apart from those that experience it;

Focus on analysis and the dissolution of systems into collections of parts;

Anticipate cause-effect relationships;

Impose external organizational structures on complex systems with the purpose being to control;

Favor homogenization and uniformity;

Establish a strong hierarchical structure for life-forms; and

Eliminates bonds of connectedness in the interest of seeking a particular anticipated/forecast result.

7.4 REFLECTING ON THE GULF TRAGEDY

This work started with a consideration of the tragic oil spill that occurred in the Gulf of Mexico during the spring of 2010. Our brief investigation into the subject of oil spills quickly unearthed a host of spills that have occurred both on land and on sea over the course of the last century. In fact, rather than being an aberration, the Deepwater Horizon accident was just one of many such accidents with the result being damage to the environment and to local communities throughout the globe. Here in the United States, we simply are kept more aware of the Gulf event and its consequences than we are informed of the even greater damage that is occurring along and in the Niger delta. That is one direct consequence of our 24-hour cable news society.

While we can never make the world safe from the next oil spill nor any other unforeseen accident, we can perhaps lengthen the odds. One way we may be able to accomplish that lengthening is a re-examination of the ethical foundation for our profession. Engineering is a value-laden profession with a strong ethical foundation.

We can begin to ask additional questions when confronted with a new design or in meeting an engineering challenge. Examples of such questions may include but would certainly not be limited to the following:

Reflection 1. Have we considered the totality of life forms, their intrinsic worth and their desire to fulfill their individual and unique potentialities in the formulation of our design response? Here

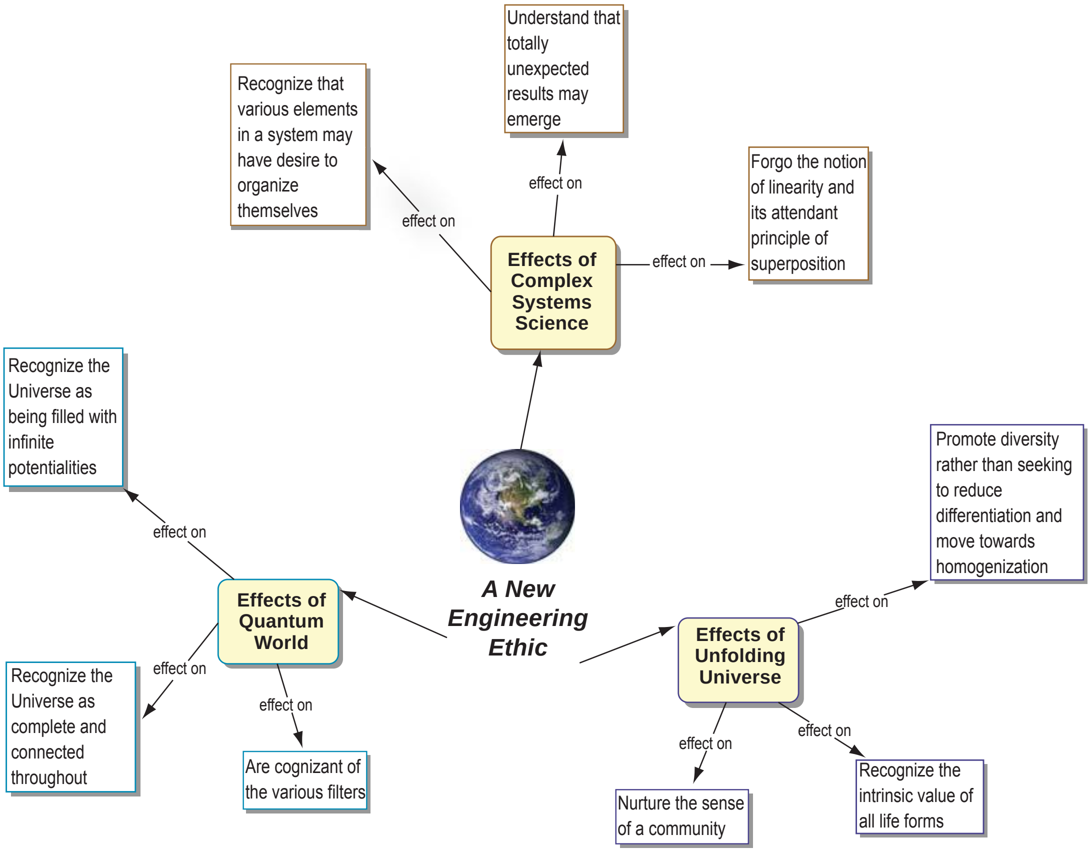

Figure 7.2: Conceptual Map of the Elements of a New Engineering Ethic.

totality of life includes our hopes, our desires and our needs as well as the hopes, needs and desires of the marine life that will certainly be disrupted and perhaps even damaged by our actions. And what of the local communities and their culture and their very way of life? Certainly, there are jobs associated with the drilling but so too may there be a loss of jobs and even more a loss of a way of life in the event of an accident.

Reflection 2. Have we considered the connections between the quality of the marine environment in the Gulf and its impact on the oceans worldwide? What will happen to the millions of gallons of oil that contaminate the Gulf waters? Will they simply go ‘away’? Where is ‘away’ anyway? Are the oceans the equivalents of what we have constructed for our waste removal and disposal on land? Are the oceans equivalent to landfills?

Reflection 3. Can we at long last acknowledge in engineering that we do not live in a linear and deterministic Universe in which past, present and future exist with certainty, much like scenes frozen for all time on video tapes or burned on DVDs and that the principle of superposition does not work? Popper used the metaphor of playing and rewinding scenes on video tapes to describe the resultant mindset of the mechanical world. I am reminded of my field, turbulent fluid mechanics. For a century or so, it was thought that if we simply had more powerful computers or more clever software or even more creative scientists, we could at long last solve the problem of turbulence, often referred to as one of the few remaining problems in Newtonian mechanics. It has not happened nor is it likely to ever happen. We are no closer to understanding turbulence today than we were in understanding it at the turn of the century…the 20th century. We cannot predict the future behavior of a flow field whether it is the flow of Mississippi River, the flow of the Louisiana coastal wetlands or the path that pollutants will take once immersed in the Gulf waters. Pretending that somehow we have constructed things so we have complete control seems the ultimate example of arrogance and hubris.

Reflection 4. Lastly, can we reflect upon the importance of the example the Universe sets for us? We have identified the laws of differentiation, of subjectivity and of communion and found their existence in this place we experience our lives. Let us reflect upon the opposites. Homogeneity—conformity—is an incredibly dangerous concept. Imagine the creativity lost, the quality of lives lessened, the potentialities never reached, the voices never heard. Objectivity, that is, dividing the Universe into 'us' and 'them' inevitably leads to a hierarchical structure in which some of 'us' are deemed much more important than either the rest of 'us' and all of 'them.' History as well as our world today is replete with horrific consequences of such mind structures. As for individualism with no connections to others, I wonder how we would ever know ourselves? Palmer suggested that is in relationships with others—other human being, other animals—that we truly uncover our own true identity. That perhaps might be the greatest loss of all—that we have lived our lives and never fully known who we really are. When we are asked to respond as engineers to a design challenge do we recognize that we are but one element in the richly diverse and intricately connected tapestry of life, each with their own unique voice?

CHAPTER 8

Epilogue

The Deepwater Horizon oil spill occurred on April 20th, 2010. Millions of gallons of oil leaked into the Gulf of Mexico. In the United States, we were outraged that such an occurrence could happen firstly but even more outraged that it could not be stopped almost immediately. Such is the confidence we have in modern technology and its agents – engineers and the practice of engineering. Certainly if we could land men on the moon, we could plug a leak at the bottom of the Gulf of Mexico, right? From my perspective even more damaging to our profession than the actual tragic event is our apparent lack of outrage. While we as a profession acknowledge it was an unfortunate occurrence, now it seems that we are back to business as usual. April seems a lifetime away. We have our finely tuned codes of ethical conduct. We have our 'body of knowledge.' Certainly next time things will be different, but now we must return to serve our clients and our corporate masters. We must help generate wealth and help add more points to the Gross Domestic or National Product. We are talking growth and jobs, or at least, that is what we are told we must do as a profession.

I would submit there is much we could learn from the Universe as a profession. We could raise our own, unique voices loud enough and often enough so we might begin to be heard. Maybe for some of us, engineering as it is practiced now is enough. I believe though, there are many of us who have been too quiet for too long, afraid to differentiate ourselves from established way of doing things. A little differentiation might be a good thing, for not only us but for those with whom we share this Universe, including the countless life forms and many different cultures. So too might it be a positive step if we look for connections rather than separateness, whether it characterizes our relationship with the external world or it ultimately characterizes the disconnectedness we find in ourselves.

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George Dominic Catalano was born in Syracuse, New York in 1951. He is a Professor of Bioengineering at the Watson School of Engineering and Computer Science, the State University of New York at Binghamton having joined Binghamton in 2000. He had previously held faculty positions in mechanical and aerospace engineering at the United States Military Academy from 1993 to 2000, and Louisiana State University from 1981 to 1993. He earned a doctorate in aerospace engineering from the University of Virginia in 1977 with an emphasis in turbulent and experimental fluid mechanics. He is the author or co-author with Caroline Baillie of six engineering monographs, has published over 150 peer-reviewed journal articles and conference proceedings in fluid mechanics as well as in engineering design, engineering education and engineering ethics. He has been awarded two senior Fulbright awards having been invited to join the faculties at the Polytechnic Institute in Turin, Italy as well as the Technical Institute in Erlangen, Germany. His current interests are in modeling ecosystems and in the impacts of engineering in both societal and environmental contexts. He is a Vietnam War era veteran having served as an officer in the U.S. Air Force.