Engineering Nonkilling

Scientific Responsibility and the Advancement of Killing-Free Societies

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“There lies before us, if we choose, continual progress in happiness, knowledge, and wisdom. Shall we, instead, choose death, because we cannot forget our quarrels? We appeal as human beings to human beings: Remember your humanity, and forget the rest. If you can do so, the way lies open to a new Paradise; if you cannot, there lies before you the risk of universal death.”

The Russell-Einstein Manifesto, 9 July 1955

Contents

Introduction

Nonkilling Science and Technology

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It was Bertrand Russell who wrote: "Philosophy begins when someone asks a general question, and so does science."

Science is not a religion or a dogma. There is a caricature of science as being composed of catalogue of facts and discovering infallible truths. In fact science is about inquiry, raising questions, and then advancing propositions that come through incremental or radical creativity. It is an open-ended process.

In *The New Production of Knowledge* (1994), Michael Gibbons and colleagues write about a new form of knowledge production is emerging alongside the traditional familiar one: "a new form of knowledge production affects not only what knowledge is produced but also how it is produced; the context in which it is pursued, the way it is organized, the reward system it utilizes and the mechanisms that control the quality of that which is produced." It is in fields such as physics, chemistry or mathematics where this new approach to knowledge has been better articulated.

The present volume is a testimony to such development of new production of knowledge. It raises an important question: what kind of science and applications needs to be engineered to work towards a killing-free world? The chapters explore the possibility of a nonkilling imperative within a context of application in that the problems dealt with are not set within a disciplinary framework but are transdisciplinary in nature. They have been, as Gibbons would describe, analysed in nonhierarchical, heterogeneously organized forms, and their conclusions remain transient in nature.

The focus of examination is on search of continuity and conflicts in the creative processes within academic discipline(s) questioning their foundations as well as applications, and their subsequent impact on societies and the humankind. Bringing forward a nonkilling approach to problem-solving, the diverse chapters provide insights into practice of engineering, mathematics, and physics, but are extensible to other sciences, pointing to the potential scope of new research agenda that could benefit from focussing on interplay between science, ethics, philosophy, politics, and human nature.

An apt summation one paper makes as follows:

> The reader may be surprised that a socio-psychological theory for approaching conflictual relationships, i.e., nonkilling theory, has been linked with scientific natural theories. From a general viewpoint, one can justify this link by remarking that in the above we argued contrarily to the common myth, according to which science is a unitarian, monolithic worldview; this myth makes each scientific sentence an abstract and absolutely sure truth of an essentially unitarian scientific thinking. Instead, we recognised inside classical physics an essential conflict between at least two incommensurable traditions. In the 20th century the new physical theories enhanced this divergence; an incompatibility between relativity and quantum mechanics occurred and even at the present time is unresolved. Moreover, a conflict is even apparent inside the foundations of economy, social sciences, medicine, etc. (Drago, this volume).

In spite of early efforts such as those of the Pugwash Conferences on Science and World Affairs and many recent initiatives such as the "Young Scientists Cooperate for Peace" Summer Academy at the Hamburg Centre for Science and Peace Research, there is a general impression that the natural and physical sciences are somewhat alien to peace research, and indeed nonkilling. This volume brings forward the opposite perspective through the generous contributions of the Nonkilling Science and Technology Research Committee members, which currently incorporates twenty individuals from a dozen countries. Previous works by many of these researchers can be found in the various reference sections, consolidating and indeed mitigating some of the possible shortcomings of this volume.

As the reader will realize, nonkilling goes far beyond the normative stand of rejecting killing. It implies the constructive engagement in societal transformation, where all fields of knowledge need to be thoughtfully applied:

> This means unequivocal engagement in abolition of war and its weapons, abolition of poverty, nonkilling expression of human rights and responsibilities, proactive promotion of environmental sustainability, and contribution to problem-solving processes that respond to human needs and evoke infinite creative potential in individuals and in humankind as a whole. (Paige, 2009: 102)

Such a deep transformation of those societal premises rooted in the widespread acceptance of lethality (in all of its forms) and lethal intent, trespasses the limits of an ideology for social change entailing a new scientific model based on the refutation of killing-accepting science. All theories that were the catalysts for significant paradigm shifts were previously dismissed as "utopian," "idealistic," and "unrealistic" (Kuhn, 1962), in this case by the institutionalized lethality-accepting paradigm, which follows society's general orientation toward the belief that affirms the inevitability and legitimacy of killing in human relations. But as Sponsel (1996: 113-114) points out, the "natural and social sciences may be on the verge of a *paradigm shift*—to include nonviolence and peace as well as violence and war as legitimate subjects for research," countering the "historic and current systemic bias of the disproportionate amount of attention given to violence and war." Sponsel calls for considering nonkilling and nonviolence seriously, systematically and intensively: "you cannot understand or achieve something by ignoring it" (1996: 14).

The concept of paradigm shift was introduced by Thomas Kuhn in *The Scientific Structure of Scientific Revolutions* (1962) as a theory to explain epistemological change through history. Kuhn suggested a model for the mechanisms that shape scientific revolution, which, in Kuhn's terms, is "a noncumulative developmental episode in which an older paradigm is replaced in whole or in part by an incompatible new one" (1962: 91).

A paradigm is not limited to dominant theories but encompasses the worldview of the scientific community at a certain point in time. Understandably, the change of the scientists' worldview is not a simple consequence of the accumulation of adverse anomalies within a discipline, but, moreover, a result of deep alterations of social, historic and cultural conditions and possibilities. A paradigm shift is thus a long social process that implies significant changes in how disciplines function, slowly modifying views on what is thinkable or unthinkable, altering intellectual strategies for problem-solving and modifying terminology usage and conceptual frameworks in a changing universe of discourse. When anomalies become more generally acknowledged, explicit discontent, new articulations of the paradigm and new discoveries proliferate. At this stage new ideas or those who had previously been consigned to the margins of academic thought are brought forward and engage the previously accepted theoretical framework in an epistemological challenge.

As Kuhn believed problem-solving is the basis of science, the success of a new paradigm ultimately depends on its ability to "resolve some outstanding and generally recognized problem that can be met in no other way" (1962: 168). Or, summarizing, being able to resolve more problems and resolve them better than its predecessor. A new paradigm implies a redefinition of science itself as problems that were previously considered trivial or nonexistent become focal points of scientific development (1962: 103).

In *Nonkilling Global Political Science* (2009 [2002]), Glenn D. Paige envisions what kind of science would emerge if the scientific community would replace the assumption of lethal inescapability with the premise of nonkilling potentiality or, in other words, if it would shift from the predominant killing-accepting perspective to a nonkilling perspective (2009 [2002]: 73):

> What values would inspire and guide our work? What facts would we seek? What explanatory and predictive theories would we explore? What uses of knowledge would we facilitate? How would we educate and train ourselves and others? What institutions would we build? And how would we engage with others in processes of discovery, creation, sharing, and use of knowledge to realize nonkilling societies for a nonkilling world?

In a "disciplinary shift to nonkilling creativity," Paige argues, the acceptance of killing as a social, cultural, political, economic, biological, technological, etc. imperative becomes unthinkable or, at the very least problematical, as both approaches are, using Kuhnian terms, incompatible and incommensurable. Certainly, if killing is considered inevitable or acceptable within the scientific community little effort will be devoted to deepening our understanding of killing and possible alternatives that will remove the conditions behind lethality. As the criteria for determining legitimate problems and solutions also change, Paige calls for a greater emphasis on the understanding of killing within the framework of a four-part logic of analysis. This focus is on the causes of killing; causes of nonkilling; causes of transition between killing and nonkilling; and the characteristics of killing-free societies (2009 [2002]: 73).

This causational approach is crucial, as each case of killing and nonkilling must be analysed seeking to understand the underlying "processes of cause and effect, however complex and interdependent" (2009 [2002]: 74). Not only is it necessary to know "who kills whom, how, where, when, why and with what antecedents, contextual conditions, individual and social meanings, and consequences," but also why and how so many in human history have chosen life over lethality when confronted with the most adverse circumstances, and why and how collective or individual transitions and oscillations from killing to nonkilling and vice-versa have occurred.

Interestingly, the fourth item in this framework implies the need to understand existing killing-free societies. Recalling Kenneth Boulding's 1st Law ("Anything that exists is possible"), Paige (and contemporary anthropological evidence) reminds us that nonkilling societies do exist in spite of having passed largely unnoticed to most in the scientific community. Following its open-ended nature, no specific model is proposed but rather a call to human inventiveness and infinite variability, appealing to "progressive explorations of ethically acceptable, potentially achievable, and sometimes hypothetically envisioned conditions of individual, social, and global life" (2009 [2002]: 75).

For the emergence of these alternatives a normative and empirical shift from the killing imperative to the imperative not to kill must occur through a cumulative process of interacting ethical and empirical discoveries. As Kuhn stated, a scientific revolution does not come about simply through accumulation, but rather through transformation, altering the foundational theoretical generalizations (1962: 85). Paige points out that this inevitably requires normative, factual, theoretical, applied, educational, institutional and methodological nonkilling revolutions. Normative ethical progression would have to move from "killing is imperative," to "killing is questionable," to "killing is unacceptable," to "nonkilling is imperative." In parallel, an empirical progression should shift from "nonkilling is impossible," to "nonkilling is problematic," to "nonkilling is explorable," to "nonkilling is possible." (2009 [2002]: 75-79).

Scientific responsibility in the advancement of killing-free society goes beyond the conflict at the foundations of disciplines, it seeks to raise questions of ethical application of the knowledge developed whether engineering, medicine or basic disciplines of physics and mathematics. In challenging the representations of of any of these disciplines as culturally neutral, two questions are raised: What is the role of mathematics, physics, computer science or engieneering, in killing? Can mathematicians and mathematics educators, for example, work for against killing and other forms of violence?

The volume explores whether integration of materialism and ethical human behaviour is possible. For instance, how far a great technical innovation of engineering can be matched by a corresponding innovation in the expression and acceptance of ethical responsibility? An example of scientific responsibility is given from The British Medical Association (BMA), which represents doctors in the United Kingdom. BMA has provided explicit guidance on the involvement of doctors in weapons development:

> While doctors may have a legitimate role in reviewing the defensive capability of weapons, the BMA considers that doctors should not knowingly use their skills and knowledge for weapons' development. It objects to doctors' participation in weapons' development for the same reasons that it opposes doctors' involvement in the design and manufacture of torture weapons and more effective methods of execution: through their participation doctors are lending weapons a legitimacy and acceptability that they do not warrant. (BMA, 2001 apud Bowen, this volume)

The choice of technologies we make as a society have significant impact on social spaces we inhabit. The choice not only determines the pattern of education, technical training, and nature of work but also quality of life. It is the type of work generated by such technology—as one chapter asserts—that should enable nonkilling values such as holisitic production, local contextualization, autonomy of work, these values can lead to conditions conducive to alleviating violence and lethality.

Nuclear deterrence is another conflicting juncture where advocates and critics have been able to engage in theoretical and simulated exploration of local and global effects of limited or full-scale nuclear war. Nonkilling and violence accepting scientists can join in constructively and critically explore the pre-conditions, processes and consequences of commitments to realize nonkilling conditions of global life. Nonkilling paradigm is not a vision of some future utopian society but essentially a way of examining and challenging the prevailing assumption in academic disciplines that killing and getting killed is an inescapable part of human condition.

This collection shows that social and psychobiological factors conducive to lethality are capable of nonkilling transformative intervention. Nonkilling capabilities in a wide range of academic disciplines, if creatively combined and adapted, can serve as component contribution to knowledge beneficial to realize nonkilling societies.

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The Scientific Nature of the Nonkilling Attitude

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An Alternative Scientific Tradition inside Western Science

In the 20th Century Indian people, although dominated by the greatest colonialist empire, conquered their national independence without weapons. Their leader, Gandhi, was inspired by the notion of nonviolence, which led him to reject all offensive means. Surprisingly, Gandhi often reiterated that he experimented with this notion scientifically, so much so that his method should be qualified as science, even as part of the natural sciences.[1]

Western scientists never recognised science as being in agreement with Gandhi's nonviolent methods. They considered science to be an abstract social product to reject as inappropriate any attempt to correlate it with a personal involvement, as Gandhi claimed. On the other hand, even a follower of the nonviolent attitude would be perplexed in qualifying his attitude as a scientific one, because science apparently lacks any ethical and religious components.[2] Was Gandhi's claim an effort to improve mutual understanding with Western people through a naïve appeal to a value of dominant culture?[3] Or, alternatively, does it represent a wise view of science? In the following I will support the latter alternative.

Actually, Gandhi, although claiming to be applying a scientific method, charged Western natural science and technology to be one of the structural violences exported by Western civilisation. Hence, his claim apparently refers to an alternative viewpoint. Which viewpoint?

Performing an analysis of the history of natural science it can be proven that since the 18th century a relevant minoritarian tradition has been present.

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[1] It is enough to recall the title of his celebrated book, *An Autobiography, or the Story of my Experiments with Truth* (1909).
[2] It is his basic criticism of the whole Western civilisation. See *Hind Swaraj* (1908).
[3] A similar appraisal is given by Sarton (1954).

Indeed, it is not difficult to recognise that the foundations of classical chemistry are at variance with the foundations of that theory which dominated the whole science along two centuries, i.e. Newton's mechanics and its improved versions. But let's inspect not only this dominating formulation of mechanics, but also their different formulations, in particular, L. Carnot's mechanics; its foundations are at variance with the foundations of the dominating Newton's mechanics. Other alternative theories include classical chemistry, L. Carnot's calculus, geometry and mechanics, S. Carnot's thermodynamics and Lobachevsky's non-Euclidean geometry (Drago, 2009, 1986, 1991a).[4]

These alternative theories are commonly ignored since some of them are considered as mere variations of the more known formulations of respectively calculus, geometry, mechanics, thermodynamics, non-Euclidean geometries; others (e.g., classical chemistry, S. Carnot's thermodynamics, etc.) are charged to be "phenomenological," "immature," Baconian (that is, lacking of advanced mathematics) theories. Yet, in 1905 Einstein originated an acute crisis in the dominating theoretical physics, since even the foundations of his theory, i.e., special relativity, were at variance with those of Newton's mechanics. This variance is just similar to the previous ones.[5] A mutual comparison of above mentioned theories will show that they share common foundations, apparently different from Newtonian ones.

In a previous work (Drago, 2009) I presented a scientific framework for looking at Western science in an entirely new way. As an alternative to the long tradition of Western philosophy of knowledge, which conceives a monist representation of science as an application of the unique Reason to the real world, this view presents theoretical science as a pluralist enterprise, that provides grounding to nonviolent and nonkilling perspectives.

Notice that in the following, and taking note of their singularities, the nonkilling imperative, when considered in its full generality, will be equated to the nonviolence principle, which belongs to the millennial Indian tradition and then was renewed by Gandhi; in other words, I will consider the nonkilling imperative as the Western version of the Eastern nonviolence principle as it is intended in modern times.

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[4] Singh (1996) illustrates a similar philosophical viewpoint, however lacking formalisation.

[5] This is the main point missed by previous Sarton's paper; it concludes with the following words: "… there is no freedom of thought concerning that body of scientific evidence." Notice that Einstein's theoretical revolution occurred at the same time (1905) as the beginnings of Gandhi's revolution (1906).

The Common Foundations of the Alternative Scientific Theories: Nonkilling Scientific Foundations

Each of the above-mentioned theories rather than organised as in Newton's theory—an apodictic system, whose truth flows from few, abstract axioms by means of a purely deductive development—is organised by focussing attention on a universal problem concerning a given field of scientific subjects; e.g., in the 19th century, classical chemistry declared the problem of discovering by which elements matter is constituted; L. Carnot's mechanics dealt with the problem of which quantities stood unvariant during an impact of bodies; L. Carnot's calculus dealt with the problem of the reality of the infinitesimals; L. Carnot's geometry dealt with the problem of calculating all elements of a given figure which is known through some elements only; S. Carnot's thermodynamics dealt with the problem of maximum efficiency when producing work from heat; Lobachevsky's theory dealt with the problem of whether more than one parallel line is possible in geometry; Einstein's theory dealt with the problem of "conciliating" the principle of relativity in theoretical mechanics with the constant velocity of light in electromagnetism (Drago, 1990, 1991b, 1988, 1991c; Einstein, 1905).

Let us remark that both Freud and Marx did not make appeals to idealised notions from which to draw their theories. The scientific theory of the most intimate conflicts, i.e., Freud's (1925) psychoanalysis, shares the previous feature: it dealt with a problem, i.e. how to cure a deep trauma in a patient. Also Marx's (1884) theory of social conflicts dealt with a problem, i.e., how to overcome capitalism in mankind's history.

Remarkably, there are some theories which are capable of arguing about many of the factors involved in the most tremendous conflict, i.e., a war. The case of strategic theories is interesting because some strategists did not theorise how to efficiently apply a brute, destructive force; rather they dealt with the universal problem of how to manage a war by linking the best arms' power with given political aims. By reading their books it is apparent that each of those theories does not suggest a technical solution composed of a list of orders imparted to subordinate people. This theoretical attitude in strategic theories characterises at least the three following strategists: Sun Tzu (350 B.C.E.), L. Carnot (1985 [1811]) and Clausewitz (1984 [1838]).

Notice also that the theory of nonkilling cannot be drawn from self-evident principles; rather, it deals with a universal problem, i.e. how a conflict in interpersonal relationships can be solved through a final agreement with the opponent.

Each of the above mentioned theories induces a new method from the commonly shared knowledge, which is capable of solving the previously stated universal problems. Such a feature is apparent in classical chemistry; chemists, although lacking in direct evidence on matter's elements, introduced an excellent method of investigation which combined the analysis and the synthesis of common substances; by this method alone they obtained an accurate list of all the microscopic elements. Similar notes apply to the other theories. In particular, Einstein started his celebrated paper by introducing a new method for measuring time by means of the usual clocks but by taking into account the finite value (c) of the signals mutually transmitted by two observers.

Notice that both Freud and Marx referred to common knowledge shared by the wider public in order to discover new methods; respectively, a new curative method consisting of a specific kind of dialog, and a new method for both forecasting and planning the social revolution.

Also, the above-mentioned strategists started their theories from common knowledge so that their books on strategy were addressed to laymen. They explain to soldiers too, why each war has to be fought by following a specific method, to be discovered case by case, except for some general guide-lines, just those suggested by those strategists.[6]

Similarly, the theory of nonkilling leads a man involved in a conflict to perform a patient and clever analysis of the commonly shared experiences of human relationships in order to recognise inside the opponent's personality an acceptable aspect, suggesting how to construct a new, specific method, capable of achieving a common agreement which solves the given conflict.

Two centuries ago, the core of the general method to organise a scientific theory in such a way, was qualified in semi-formal terms by L. Carnot in order to improve the old "synthetic method." He developed this general method by interpreting infinitesimal analysis, i.e., the most powerful advancement in the history of modern mathematics (Carnot, 1813: 217-253).[7] He remarked that its genius consists of the following sequence of moves. One introduces "adjunctions" to a given system in order to generalise this system so that the

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[6] This point is illustrated by the following papers: Angelillo and Drago (1997); Covone and Drago (2000); Drago and Pezzella (2000).

[7] He was a scientist, a strategist and one of the leaders of French revolution. In particular, L. Carnot's strategy was aimed at defence only, through the least loss of human lives; he was the first political man favourable to conscientious objectors for political reasons. On his scientific activity see Gillispie (1971). A more recent and complete book is Charnay (1990).

search for a solution of the probem at issue is made easier. Once the solution is obtained, the auxiliary variables are suppressed in order to reduce the system to the initial system. For instance, in the ancient infinitesimal analysis one adjoins—to a mathematical system to be solved—some auxiliary variables, called infinitesimals, which, after having obtained the solution, are "suppressed" through some mathematical trick (e.g., by evaluating them as quantities too small to be appreciated; more currently, by a limit process; etc.). In his mechanics, L. Carnot adjoined "geometrical motions," which in the simplest case represent changes of the reference frame; since these motions constitute a group of transformations of the mathematical formulas representing the physical system. In fact Carnot started the first mathematical group theory. By applying the different groups of geometrical-temporal transformations, he obtained the classical invariants of motion.

In Freud's psychoanalysis a patient "adjoins" his dreams to his personality in order to offer to the analyst a clarification of his psychic "system." Marx considered as a trigger eliciting the wanted change in mankind's history, the adjunction of the suitable historical consciousness to the proletariatarian class, oppressed by the capitalist "system."

Among the strategic theories, L. Carnot's defensive one is expressely based upon the notion of "adjunction." When a besieged of a stronghold is threaten by a besieger applying a step-by-step strategy for approaching with impunity the stronghold, then the besieged, in order to break the besieger's strategy has to "adjoin" to his inside defensive activity some quick ouside sorties.

In the theory of nonviolence, Aldo Capitini—the first European nonviolent activist—independently offered a philosophical basis to the method of adjunctions. He considered the whole development of Western philosophy. As it is well-known, Kant recognised that human reason unsuccessfully attempted to know the essence of beings of the external world (*noumenos*); however Kant (1793) suggested that one can achieve reality through an ethical move, characterised as an "adjunction." Hegel's philosophy translated this notion into an idealistic one, the *Aufhebung*, which is an Absolute Spirit's move for transcending the historical reality. Instead, Capitini considered the "adjunction" at no more than a personal level; it is aimed to raise the level of an even distressing situation of interpersonal relationships, and hence to achieve a higher viewpoint, which makes it easy to envisage a "choral" solution.[8] According to Capitini, this process constitutes the essence of nonviolence.

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[8] Among Capini's writings on this subject, the most appropriate one is "L'avvenire della dialettica," in Cacioppo, Ed. (1973). A short synthesis can be found in Altieri (2008).

Indeed, in Gandhi's conception of nonviolence this notion is substantiated by at least a prayer; or as an intermediate action, a fast; or as his maximum effort, his own sacrifice to death.[9] Therefore, the process of nonkilling solution of a conflict can be modelled by attributing to the notion "adjunction" the same role it plays in scientific theories (Drago, 2007: section 2.7).[10]

A formal interpretation in logical terms

The common features of these theories now will be qualified in formal terms, first by mean of mathematical logic (however, without involving sophisticated notions). In fact, all these theories follow nonclassical logic. In classical logic the law of double negation holds true; it is commonly stated as follows: "Two negations affirm" (e.g., the statement: "It is not true that 2+2 is not 4" is equivalent to the statement: "2+2=4"). But this law may fail; e.g., a Court's judgement of "lack of guilty evidence" is not equivalent to its corresponding positive judgement of "honesty." According to recent studies in mathematical logic (Prawitz and Malmnaas, 1968; Dummett, 1977; Dalen and Troelstra, 1988), this failure characterises nonclassical logic.

An inspection of the original texts by the authors of these scientific theories shows that they include a lot of double negated sentences (DNSs), whose corresponding positive sentences are not true for lack of scientific evidence. Some instances of DNSs are the following ones: "It is impossible that matter is divisible in a not finite way" (chemists of 19th century); "The infinitesimals are not chimerical (=not real) beings" (L. Carnot); "It is impossible a motion without an end" (L. and S. Carnot); "It is not true that heat is not equal to work" (S. Carnot); "It is not contradictory the hypothesis of two parallel lines to a given straight line" (Lobachevsky); "... we can attribute no absolute (=not relative) meaning to simultaneity." Each of the above statements is not equivalent to the corresponding positive statement, since the latter one lacks scientific evidence in experimental terms.

Let us remark that even the scientific theory of the most intimate conflicts, i.e., Freud's psychoanalysis, shares the same features. A Freud celebrated methodological paper illustrates how the analysis of a patient's diseases starts (1925). When a patient, by telling the analyst his dreams, says a negated state-

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[9] Also Sarton remarks this point by stressing that Gandhi "was always ready to be the scapegoat of India" (1954: 97).

[10] One may improve this joint theory by considering the theory of impact of bodies as a theory of conflict resolution. See Drago (1996).

ment: "I did not want to kill my mother," then, the analyst has to add a second negation to this statement: "It is not true that he did not want to kill his mother." In such a way he obtains a hint to recognise a patient's trauma.[11]

It is well known that *Marx* wanted to shape his entire theory by means of a "new dialectical logic," where the synthesis between thesis and antithesis is obtained by a "negation of the negation" of the starting thesis.

The original texts about the above-mentioned strategic theories present a great number of DNSs. For example, the main goal of each strategic theory is not to win all wars, but to result in an invincible Army (Sun Szu). L. Carnot's main statement may be considered: "it is not true that war work is not civil work [to build a stronghold]." Moreover, the most celebrated Clausewitz statement is "War is nothing else but diplomacy through different means." (He never wrote the corresponding positive statement which is wrongly attributed to him by almost all scholars.)

Nonkilling thinking is essentially merged in nonclassical logic, since the word nonkilling is not one negation, but two negations—being of course that killing is a negation of life; the same holds true for the word "nonviolence" (Horn, 1986: 84). In fact, this double negation cannot be appropriately replaced by a concrete, positive word. According to Gandhi the best candidate for this replacement is the word *satyagraha*; yet, this word sublimates the original meaning of nonviolence into abstract words (in particular, the word "Truth"), overhanging human life. Hence, both words nonkilling and nonviolence are DNSs. As a consequence, any typical slogan which is consistent with the nonkilling attitude is appropriately expressed by two negations; e.g., "Do not harm," "Never more [nuclear bombing] Hiroshima!" Two more crucial words in Gandhi's thought were two DNSs: *aparigraha* (nonpossession) and *advaita* (nondisunity).[12] Christian people commonly think that the positive word "love" is equivalent to—and even more meaningful than—both "nonk-

[11] Actually, Freud was not so explicit. However his crucial statement "the negation is a way to get knowledge of the removal," attributed by him to the patient, also holds true for the analyst. See Drago and Zerbino (1996).

[12] For some instances, see Gandhi (1958, ch. 4, No. 8, 43, 52, 76). However, some more crucial Gandhi words, as *Bramacharya*, are positive words. Hence, Gandhi was not always consistent with the formally inductive way of arguing. In this sense one may remark both "a confusion" (id., 100) and a "zigzag" (id., 91), which however Sarton enlarges to the entire Gandhi's thinking.

illing" and "nonviolence"; yet, "love" is a fuzzy and multi-purposed word, as it is proved by the social history, actually full of wars, of Christiandom.[13]

Let us notice that human rights may be viewed as forcing corresponding affirmative versions some DNSs, say the last five commandments (the social ones). In particular, the commandment "Thou shalt not kill" has been forced into "Right of survival," "Right to develop his own life," "Right to have access to life resources," etc. The examination of this short list tells us that, in order to exhaust the meaning of a DNS by translating it into affirmative sentences, one has to produce a lot of them. It is not by chance that the UN Declaration of Human Rights is unsatisfactory to many, who want to add to the list of this declaration the second, third, fourth…generations of rights. Hence, both nonkilling and nonviolence are not equivalent to any finite set of affirmative sentences.[14]

The dichotomy between the two kinds of logic enjoys a noble philosophical origin. Leibniz sketched a "Science of Science" (Drago, 1994) whose two basic principles are the principle of noncontradiction and the principle of sufficient reason; the latter one, being in itself a DNS ("Nothing is without a reason") constitutes the best principle for arguing according to nonclassical logic—i.e., in an inductive way—inside an alternative theory (Drago, 2001, 2003). In fact in each of the above theories one recognises the translation of the latter Leibniz' principle in a particular DNS, which in the theory plays the role of a specific methodological principle. Respectively: "No efficient calculus without reason," that is: "The infinitesimals are not chimerical (=not real) beings" (L. Carnot's calculus). "Nothing is without parts," that is: "As an element we call any substance which is not still decomposed" (Lavoisier). "No parallelism without a proof," that is: "We will call parallel line any straight line which by means of a least deviation intersects the base-line" (Lobachevsky's non-Euclidean geometry); "No motion without a reason," that is: "It is impossible a motion without an end" (S. Carnot's thermodynamics).

In Freud's theory: "No patient's negation without a reason." In Marx' theory: "No capitalism's move without a reason". In strategic theories: "No move in a war without a reason." In conflict theory the principle of sufficient reason may be applied almost directly: "No evil is without a reason." It leads to directly think which positive reason may be recognised in the opponent.

Some of the above-mentioned theories present one more feature which proves that DNSs play an essential role inside an alternative theory; the

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[13] I illustrated this point in the end of Drago (1992).

[14] This point is one of the first results on the comparison between classical logic and nonclassical logic. It was obtained by Goedel (1986 [1933]).

mere sequence of DNSs recognised inside an original text faithfully summarises the core of the respective theory. This occurs in S. Carnot's booklet on thermodynamics (Drago and Pisano, 2000), Lobachevsky's new geometry (Drago and Perno, 2004; Drago, 2007), Freud's psychoanalysis (Drago and Zerbino, 1996), and the above strategic theories. This fact gives evidence for the essential role played by the DNS in the development of each of the above theories. Also Gandhi's argument, aimed to positively solve conflicts, includes a great number of DNS. For instance, his celebrated book develops through DNSs (Drago, in press).

A comparative analysis of the above theories shows that nonclassical argument by means of double negated sentences achieves results by means of *ad absurdum* theorems. The best instance of them is in thermodynamics—the celebrated S. Carnot's theorem which also presently is taught to the students of Physics and Engineering. [15]

In Marx' theory several *ad absurdum* arguments are included in his works. An example: "He [the capitalist] is unable to understand that, if really existed one thing as the value of the work and if he really payed this value, [absurd consequence] no capital would exist and his money would not change in capital" (Marx, 1884, Book 1, section XVII).[16]

Also the *strategic theories* end by *ad absurdum* arguments. In his main strategic writing, L. Carnot presents three *ad absurdum* arguments. The main one is the following one: "Because, if the enemy is robustly placed on the paths leading to the stronghold, it would be absurd to go to present to him the fight together with a garrison which on the contrary one has to preserve so much as it is possible" (Carnot, 1985 [1811]: 32). Clausewitz presents several *ad absurdum* arguments; e.g. the following one: "…in their actual notion, the wars are nothing else than *ad absurdum* manifestations of the politics itself, as we showed in the above. Thus, it would be absurd to subordinate the political views to the military viewpoint, because *the*

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[15] An *ad absurdum* argument concludes by means of a DNS, i.e., *not-not-UT* Classical logic can translate it in the positive sentence *T*, by applying just that law of double negation which fails in nonclassical logic. In a theory arguing through DNSs, the last DNS works as a methodological principle for the next argument; hence, the classical logic is not necessary for advancing lucid and formal arguments according to nonclassical logic.

[16] Freud's short paper does not present *ad absurdum* arguments. However, two facts are relevant: an entire page dedicated to the principle of reality, that is nonabsurdity; the conclusion of the paper is that "no 'not' comes from unconscious," that is the principle upon which his entire chapter relies, and which could play the role of the principle from which absurd is obtained: "it is absurd that the unconscious suggests a 'no.'"

politics generated the war; the former one is the intelligence, whereas the war is nothing else than the instrument; the opposite would go [*absurdum*] against common sense. It remains nothing else to subordinate the military viewpoint to the political one" (1984 [1838]: book VIII, vi, b.).

The eventual result of the nonviolent method is obtained by reducing an argument *ad absurdum;* e.g. "It is absurd that my opponent is not my brother, otherwise God does not exist," or "…otherwise universal brotherhood is impossible." Gandhi often argued in such a way; for example, the well known sentence: "Eye for eye (=the law of the vengeance) makes the world blind"; that is "Vengeance is absurd; hence it has to be rejected." He was so rooted in this way of arguing that he claimed "There is no God but Truth"; in other words: "In the absurd, no God."[17]

The final argument of the theory achieves, again by means of an *ad absurdum* theorem, universal evidence concerning all problems at issue, i.e., the universal DNS *not-not-UT*. Owing to its universal nature the author feels himself justified in changing it in the affirmative predicate *T*, which then is assumed as a new hypothesis from which to draw all possible derivations. This move, changing both logic and the theory organisation, is apparent in both S. Carnot's thermodynamics (after this theorem, he changes the resulting DNS ("The efficiency of no reversible heat engine is less than the efficieny of an irreversible heat engine") on the maximum efficiency about all heat transformations in work into a hypothesis ("The efficiency of a reversible heat engine is the maximum one") from which he draws new laws on specific heats and gas) and Lobachevsky's theory (after his main theorem, prop. 22, he changes its result about all straight lines and all triangles in the hyperbolic hypothesis from which he draws all geometrical consequences) (Carnot, 1813: 50; Lobachevsky, 1950 [1840]).

In Freud's paper, the DNSs concerning a patient's trauma is directly stated as an affirmative sentence, "hence, it is the [relationship of the patient with] his mother [the cause of the trauma]," from which the analyst tries to draw all the consequences of the present patient's personality.

Moreover, *ad absurdum* theorems close both L. Carnot's and Clausewitz' strategic theories. Previous *ad absurdum* argument may be considered Clausewitz's final argument; the final quoted sentence is the universal sentence *UT* concluding the theory.

It cannot be overemphasised that some of the above scientists, although unaware of nonclassical logic, almost consistently built their theories through

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[17] Other instances of this argument in ch. 4, No. 8, 43, 52, 76 (Gandhi, 1958).

both DNSs and ad absurdum theorems so that they followed a common model of organisation of a scientific theory.

In the theory of conflict resolution this last move corresponds to the change from inductive argument about which may be the key to understanding an opponent's personality, to draw from this key a first initiative, e.g., to launch a mutual dialog for peace. In the case of the above quoted Gandhi's DNS about Truth, after having claimed that "There is no God but Truth," he then changed it in his celebrated sentence: "Truth is God."

By linking the foundations of conflict resolution with the foundations of some scientific theories, we have characterised in a scientific way both the kind of logic and the alternative organisation of a theory of nonkilling. Two more facts support this connection; already in the 17th century Leibniz exploited his theory of impact of bodies—where his notion of elastic body interprets a possibly disastrous impact in an exchange of common quantities (i.e., momentum, momentum-of-momentum and energy)[18]—for constructing a theory of interpersonal conflicts where the corresponding notion of a flexible attitude may lead the opponent to recognise common values (Leibniz, 1671; Drago, 1996).[19] Moreover, L. Carnot's celebrated strategy paralleled his general theory of machines (that theory which originated the modern discipline of technical physics); i.e., he conceived a stronghold as a machine whose laws about the work's balance may suggest how to theorise the principles for stronghold defence (Drago and Sasso (1993).

[18] His theory was an alternative to Wallis' and Newton's theory of the impact of bodies as based on the idealisation of a perfectly hard body, so that it does not bounce. By translating this physical notion in the interpersonal relationships, it is easy to recognise in it a macho attitude.

[19] As a further verification, let us remember that recently a similar—since it is a global and conflictual—viewpoint on scientific theories has been reached by seeing all of them from a historical viewpoint. Koyré, Kuhn and some other historians stressed that history of science is essentially conflictual in nature (Koyré, 1957; Kuhn, 1969). By generalising the categories by both Koyré's and Kuhn's historiographies, I obtained new categories for a new historiography which is capable to faithfully represent the above illustrated conflict inside science (see Drago 1991a, 1994, 2001). Conversely, the conflictual theories of the history of science suggest a general theory of conflict resolution, whose main methodological principle is "Thou shalt not kill," and which moreover results to include the nonviolent theory (Drago, 1996; 2007a). It results also to generalise Galtung's theory (1976, ch. 1, 2, 1999).

A Formal Interpretation in Mathematical Terms

Let us remark that not one of the above scientific theories use actual infinity, through infinitesimals or differential equations.[20] In philosophical terms, their infinity is the potential one only; for instance, the numbering of natural numbers, which usually excludes the existence of a maximum number, since it is a manifestly idealistic notion.[21] Yet, scientists introduced actual infinity in mathematics and in theoretical physics too (e.g., the extreme points of a straight line, although no one went at these infinite points; or the classical divergences in the central point of a force field, say the gravitational field; or the words: "All body…" in the statement of Newton's inertia principle, although we will never exhaust the list of all bodies in the world). Whereas the former notion of infinity leads us to see universality as an unlimited addition of ever more units, the notion of actual infinity obtains the universality by a jump to an extreme result, which is detached from any approximation, first of all, in logical terms, by using the word "all" which is the equivalent of the total quantifier. The former notion leads one to proceed by a step-by-step process of calculation or construction, the latter one leads one to proceed by guessing ever more idealistic notions, provided that their consequences successfully apply to the reality.

In the former attitude never one says "All…," but "No man excluded…"; nor "There exists…," but "One is enabled to construct an instance…" Also the nonkilling attitude can be characterised through its choice for constructing interpersonal relationships involving even more men, rather than possibly mythical ideas or institutions. In particular, it leads one to say: "No one is an enemy," not "All men are brothers."

By adding this option of the kind of infinity to the above one on the kind of organisation, one obtains two dichotomic variables which generalise the two dichotomic variables sketched by Galtung (1976) as generating the notion of four models of development;[22] according to Galtung, these models characterise a nonviolent political theory (Drago, 2007b).

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[20] A specific inquiry on Einstein's paper on special relativity shows that the first differential equations can be translated with impunity in mere difference equations.

[21] This conflict in the foundations of mathematics, i.e., between the constructive one and the classical one, is illustrated by the "Manifesto" in Bishop (1967).

[22] The two dichotomies we have recognised agree with Gita's teaching about human knowledge, as constituted by two irreducible chords, i.e., the Unity and the Infinity [Lanza del Vasto (1993 [1954]: 18-19]. In my view, Unity represents a positive choice on the option on the kind of the organisation of the theory at issue, or

Conclusions

The reader may be surprised that a socio-psychological theory for approaching conflictual relationships, i.e., nonkilling theory, has been linked with scientific natural theories. From a general viewpoint, one can justify this link by remarking that in the above we argued contrarily to the common myth, according to which science is a unitarian, monolithic worldview; this myth makes each scientific sentence an abstract and absolutely sure truth of an essentially unitarian scientific thinking.[23] Instead, we recognised inside classical physics an essential conflict between at least two incommensurable traditions. In the 20th century the new physical theories enhanced this divergence; an incompatibility between relativity and quantum mechanics occurred and even at the present time is unresolved. Moreover, a conflict is even apparent inside the foundations of economy, social sciences, medicine, etc.

On the other hand, the connection of nonkilling theory with scientific theories holds true also in the opposite direction. Indeed, even a scientific experiment is essentially a conflictual process. The outcome may be called a successful scientific result only when an agreement is reached between the positive answers by the experimental data and the researcher's previous hypothesis. All the above substantiates Gandhi's words on both his experiments with truth and the scientific nature of nonviolence.

When science is conceived as including an essential conflict, its abstract and sure nature collapses in the nature of a merely human initiative, which therefore may be analysed in connection with interpersonal relationships.

In the past, Western civilisation led people to conceive in a unitarian framework all scientific theories on "reality" and at the same time to consider as an inescapable necessity—at least, in extreme circumstances—the need to judge some conflicts as essentially impossible to solve, so to consider enemies as evil to be suppressed. At present, nonkilling attitude leads us to turn up this attitude; i.e., we have to maintain that the several systems of scientific thinking are mutually incommensurable (likely religious beliefs are); and rather, to consider as ethically inescapable to conciliate conflicting

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equivalently on the kind of logic; and Infinity [path to God] represents a positive choice on the option of the kind of infinity, or equivalently on the kind of mathematics of the theory at issue. Let us remark that Lanza del Vasto (1959, ch. 1) was capable of masterly criticising science through two of Christianity's holy texts.

[23] So sure to be able to solve any conflict, provided that we are able to formalise it in a scientific expertise.

persons, by viewing all of them inside the organistic unity of the universal brotherhood, as constituting the only true reality.

This change translates in theoretical terms what in philosophy Capitini had already suggested as the conversion of the human mind to an ethical attitude. Hence the nonkilling attitude is at the same time an ethical attitude and a scientific attitude, provided that for "scientific" one means the alternative methodology and philosophy of science.

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Nonkilling, Professional Ethics, and Engineering the Public Good

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Taking illness to a physician, only a few centuries ago, was likely to result in the unnecessary loss of blood, if not premature death. The source of illness was occult, treatments were dangerous, and so more conservative physicians simply focused on methods that, if ineffective, were at least something less than immediately fatal. Physicians had physical contact with their patients, witnessed their suffering, and felt their loss. The concerned practitioner might draw a little blood, in a variety of ways, and thereby safely demonstrate both erudition and industry—encouraging the patient toward silence, if not health.

But because of the potential for harm, and because of their familial concern for the individual, ancient physicians chose the professional caveat: *Primum Non Nocere*. The potential for harm was, indeed, obvious, as well as morally compelling. And although germ theory gave physicians an important influence on *society*, doctors have retained the Hippocratic Oath in deference to their continued focus on the *individual*.

Engineers, similarly empowered with Baconian methods, address the community need for infrastructure, rather than healthy individuals. As a consequence, engineers primarily consider the potential for harm on a communal scale, and *our* professional constraint is to *hold paramount the public safety, health, and welfare*. Unfortunately, a lot of individuals can and will suffer before the *public* safety, health, and welfare even breaks a sweat. Further, because engineers primarily deal with an abstract social structure, rather than with individuals, engineers do not often see the anguished faces of those they impact. Historically, engineering developed as a branch of the military, and has no *explicit* professional constraint against doing individual harm (killing, being the extreme manifestation).

"Civilian" engineers acknowledge a professional duty to serve the public good, but we, arguably, have an even deeper, personal duty to respect individual life. After all, the public good is not defined by consensus, and even if it were, majority rule is practically, rather than morally compelling. Most governments consist of leaders making decisions (some of which, engineers are expected to carry out) on behalf of the governed. But while even a *tyrant* might choose to define a public good that allows individual, human flourishing, the "public" is a social construct that does not bleed. When the public good tramples on individual life—even for the greater, actual good of collective individuals—diminished life compels us to respect a remainder obligation toward those suffering a socially imposed burden. While it might be comforting, engineers cannot simply shunt the administration of social justice onto someone else: we are morally obliged by the remainder obligations generated through our work.

The line between killing and letting die is fuzzy at best, and engineers need to reexamine their willingness to let individuals suffer for the greater good generated through engineering projects. Deaths, causally associated with a particular project, might be human or nonhuman; intentional or accidental; foreseeable or unforeseeable; immediate, proximal or distal. But when an individual's death is attributable, at least in part, to an engineering project, that individual bears a kind of ultimate, social burden that cannot be distributed back and relieved by the society in general. Increasing the balance of good *overall* simply is not enough—our engineering projects need to avoid, mitigate, or *at least* respectfully consider the disproportionate burden born by those who suffer and die in the aftermath.

While *ahimsa* (nonkilling) has seldom been the focus of engineering, even with benign projects such as the delivery of clean drinking water, this deficiency is a moral failure resulting from a paternalistic sense of professional duty that "treats" the beneficiary, and, too often, ignores the collateral individual. This does not make our engineering designs *bad*, it simply makes them incomplete. It would be *wrong* for us to knowingly put forth an incomplete design; or to ignorantly put forth a design that we considered "complete" as an exercise in wishful thinking. On the other hand, if we *unknowingly* allow an incomplete design to progress through to realization, then we have committed an error of omission. While our motivation remains untainted, we are nevertheless obliged to correct mistakes as they come to our attention, and relieve inappropriately assigned burdens.

For example, the Golden Gate Bridge, completed in 1937, was a stunning engineering achievement, which must have been personally gratifying for the engineers involved. Realizing a greater good for thousands, the Bridge was an aesthetic, economic, and moral exemplar. The elegant lines, austere setting, and extreme attenuation (its 4,200 feet was the world's longest clear span at the time of completion) make the Bridge a globally identifiable symbol of built beauty. While the Bridge was actually constructed *under* budget by $1.3 million, its exquisitely optimized main cables compare tellingly with the grossly over-designed structure of its contemporary, the record-setting Empire State Building (the main cables were so finely tuned as to thwart subsequent attempts to add the second traffic deck, common on less sleekly-spectacular Bay bridges). Finally, as has been frequently noted, Bridge construction pioneered the use of safety nets to protect exposed workers—saving 19 from assumed-fatal falls, and reducing the number of construction deaths to less than a third of what might have been expected by rule of thumb.

Yet, any engineering project interacting with individuals—even drawing nothing but awe and respect from most of us—is liable to entail *some* moral obligations. For this analysis, I would like to examine the Bridge, and consider those moral obligations that accrue subject to the potential for loss of life. With regard to *human* life, we need to consider:

- Accidental death during construction, and in traffic (on the Bridge itself, but also due to increased regional traffic generation)
- Intentional death through suicide, and from armed attack (on the Bridge, as a military or symbolic target of opportunity)
- Increased mortality from economic adjustment (among economic pilgrims, as well as the marginalized and excluded)

Additionally, I think we need to consider the death of animals:

- Directly as road-kill, and indirectly through displaced habitat (attributable to the increased number of vehicles, roads, and communities enabled in the North Bay counties by the Bridge's construction)

In each of these instances, Bridge engineers missed an opportunity to lessen the potential for loss of life, failing to commit adequate resources to understand incipient problems and realize effective solutions. If there is a failure here—with the stunning engineering success of the Bridge, and by inference, perhaps, with our more yeoman engineering designs—I feel that it might be justifiably laid at the foot of our professional ethic, which avoids an explicit reference to the individual.

Accidental Loss of Human Life

Compared with the past, we seem less willing to simply accept the untimely death of a distal other. This is equally true of intentional, unintentional, and accidental death. In terms of intentional death, at least some responsible actors in our (US) government believe this, or they would not feel compelled to obscure the level of carnage now taking place in the Middle East (no one similarly placed was concerned enough to conceal our level of troop loss, an order of magnitude greater, 40 years earlier in Vietnam). As for unintentional death, the epidemic of puerperal fever recognized in Vienna by Ignaz Semmelweis, might today generate outrage, rather than a 19th century blend of ignorant denial and helpless acceptance. Finally, the expanding scope of current safety features indicates less complacency with *accidental* death, if not an increased willingness to relieve the suffering of victims (still distributing relief primarily on the basis of insurance).

I can remember working on construction projects where safety equipment was minimal to nonexistent by current standards. I also remember a lot of old carpenters with missing digits, and was more-or-less amazed to discover that they had lost fingers, like Civil War saw-bones, through haste and a well-sharpened hand tool rather than the introduction of unfamiliar and obviously dangerous power equipment. The greatest dangers are often concealed—sometimes behind over-reliance on safety devices—but individual accidents derive as much from human attitudes as innately perilous operations. Danger accrues to an industry as a function of process, rather than the ultimate industrial product.

Historically, the risks of a dangerous profession were naively assumed to be inevitable, and the subject of informed consent. Dangerous jobs often entailed higher wages, and the idea was that greater compensation—compensation for risk—was also adequate compensation for the burden of accidental loss. Payment for risk is fine, but the idea that there can be just, monetary compensation for accidental death is ludicrous. No one, in the absence of insanity, terminal illness, unbearable pain, or the duress of an impossible situation, would volunteer to surrender a *limb*, let alone end his or her life, purely for the sake of monetary compensation.

Yet in the recent past, industrial accidents were considered an act of God (or a random act of chance) rather than ultimately preventable occurrences, statistically skewed to particular industries by ignorance, greed, and neglect. Workers were given the economic status of a raw material—to be used up, or replaced by raw material from another source if prices became too dear. (If you believe this practice to occur *strictly* in the past, try hiring your neighbor to raise, slaughter, and clean the chicken you want to cook for dinner.) Injured long-term workers were typically dismissed with some minimal package of benefits, while short-term workers and the families of industry fatalities were left to the spotty care of external charities.

In a similar way, traffic fatalities were accepted as the simple inevitability of hurling people around at 70 miles per hour, surrounded by a ton of glass and metal, and oozing a few gallons of accelerant. The car I have owned for the last 18 years (a 1964 Plymouth Belvedere, which has never had seat belts) was built and originally purchased in 1963, the first year U.S. traffic fatalities topped 40,000. By way of comparison, annual traffic fatalities always exceeded our troop losses in Vietnam (by more than a factor of 3, even during the year of the Tet Offensive). While traffic fatalities reached an apex of nearly 55,000 in 1972, the increasing emphasis on "safe" vehicles has reduced U.S. traffic fatalities to mid-1960s levels. But historically, so many people died before their time, subject to accidents, infections, treatable or preventable disease, as collateral damage in wars, or subject to the vagaries of food production and famine—we just stoically accepted the fact that our lives would be touched, at various points, by premature death.

We seem more active today, looking for culpability in accidental death and assigning damages. I suppose it is tempting to play a utilitarian analysis with human life. Perhaps we imagine a minimum market value in terms of some abstract utile, like dollars (e.g., how many waking hours might a relatively alert human expect to live, and how much would the reasonably competent require, as compensation, to relinquish one hour). Market force estimations, after all, form the basis of how we value a (nonpet) animal life (so much per mature pork-belly, delivered to the abattoir, depending on timely supply and the instantaneous, global yen for bacon). And, of course, market forces were also used by slave owners, to place a value on "available" African-Americans before our Civil War.

But the assignment of damages, too often, is a *post hoc* measure of retributive, rather than distributive justice. Since a lost human life is irredeemable, unless, possibly, in exchange for some "equivalent" human life, justice after the fact is an illusion. Engineers should do their best to design useful projects, which enhance life—not to avoid damages, but because moral behavior is morally compelling. If fatalities occur, we need to correct the immediate and responsible causes, insure that the fatality is not simply accepted as the cost of doing business, and ease the burdens of those who, in Whitman's terms, remain, and suffer. But justice is temporally beyond our grasp. Justice demands our attention *before* dangers become *de facto*.

The Golden Gate Bridge and post-war automobile safety requirements are rightly cited as the beginning of a gentler, more responsible attitude toward the victims of fatal accidents. Innovators like Joseph Strauss and Preston Tucker were obviously unsettled by the existing, callous attitude toward accidental loss of life—and in their own ways, are at least partially responsible for leading our society away from its complacency. But Strauss and Tucker's innovations addressed *familiar* accidents, and made no real attempt to consider safety problems beyond the expected (e.g., failing to account for gondolas crashing through safety nets, or lead poisoning from automobile exhaust emissions). Since many engineered works outlive their designers, we need to devote a significant portion of the design effort to considering just how each project might encounter an adjunct failure in unexpected and catastrophic ways (perhaps writing, disseminating, and critiquing imaginative reports). With the collective imagination of the engineering profession, I do not see why we would be unable to anticipate at least some of the new forms of accidents which inevitably follow in the wake of new technologies.

One might argue that the extreme boundaries of killing (intentional) and letting-die (accidental) encompass a well-distributed continuum of possibilities. While no single contribution to an accidental death may be necessary or sufficient, there is perhaps *some* culpability by simple contiguity (this seems to be the direction taken in U.S. civil suits, assigning minimal, potential liability to caterers, for construction deaths at the sites they service). This being the case, there is a fractional aspect of killing associated with accidental death that makes our professional concern morally imperative. Perhaps accidental deaths are simply unintentional killing, as with the ignorant introduction of bacteria during childbirth in 19th century Vienna.

Intentional Loss of Human Life

There are probably two types of intentional death one might associate with the Golden Gate Bridge—suicide, which has occurred (often) and should reasonably have been anticipated; and politically-motivated attack—blowing up the Bridge as a military objective, or as a symbol of something else, hateful, yet beyond weapon's range. While both types of deaths are, or would be killing (you cannot really argue Secondary Effect here—that someone might want to blow up the Bridge, without intending to kill the people driving across it in their cars), they otherwise seem to be quite different.

Suicide is certainly a killing, but the *ill* of a suicide's death seems to be a function of motivation; we do not consider willing, self-sacrificial death to be suicide *or* killing—even if the sacrifice achieves nothing concrete. For example, the unsuccessful hero might use his body in a vain attempt to save someone else. Comparatively, a *suicide* might choose to die because he thinks it would be better for his family. Both deaths are untimely, but we hold the suicide particularly culpable because we consider him inadequately informed, and think that he ought to have known better. We are less judgmental of the thwarted hero, and consider the world a better place, because of the occasional human willingness to make the ultimate sacrifice in an attempt—even if unsuccessful—to save the other. But if the suicide cannot know the state of the world in his absence, then neither can we. Further, if the culpability of *accidental* death exists somewhere on a continuum between killing and letting die, then perhaps suicide itself might not be an *absolutely* culpable form of killing (might retain a residual element of the accidental).

If a particular suicide *were* considered morally acceptable—for example, by controlling the manner, rather than the time of death, thereby avoiding a death that could be considered significantly premature—then jumping from the Bridge under the proper circumstances (no witness, no family or musing comrades left behind to wonder, and an out-going tide) might avoid censure. Under the right circumstances, the suicide would mitigate the physical aspects of a messy aftermath; and we know that the "well-tested" probability of success would be 98% (greater, if the suicide could control the angle of impact).

But if there were a morally acceptable suicide, it would be difficult to differentiate ahead of time. And for the purpose of this analysis, I will assume (along with Kant) that there is a perfect moral imperative against suicide—that suicide is a killing similar to the killing of someone other than yourself. This being the case, the engineers who designed the Golden Gate Bridge should have considered features to deter *all* potential suicide.

Of course, as originally configured with a pedestrian lane, the Bridge might be considered "suicide friendly." Does the aesthetic Bay view seen from the walkway (admittedly stunning) offset the "attractive nuisance" appeal for potential suicides? On the other hand, lazy, or less-ambulatory suicides have certainly been willing to abandon cars on the roadway. More to the point, since suicides were jumping from the Brooklyn Bridge long before the Golden Gate Bridge was envisioned, the Bridge's popularity with West Coast suicides should not have really surprised anyone.

As of 2005 (68 years of operation) more than 1,200 Golden Gate Bridge suicides have been documented (currently compiling at about one every two weeks). Importantly, there has been a continuing effort to reduce suicide attempts—through signage, alert officials (many potential suicides being thwarted by the California Highway Patrol) and with the introduction of sensors and strategically placed suicide nets. Perhaps there are additional *post hoc* palliatives (e.g., handing out anti-depressants at the pedestrian turnstile), but suicide prevention should have been incorporated into the *original* design. Again, as with accidental death, *most* people will eventually recognize a problem and potential solutions, but engineers are particularly well-trained to consider technical problems in the abstract. And a brainstorming of unimagined, destructive applications should be a part of every engineering preliminary design. If this had been accomplished in the 1930s, perhaps the Bridge suicide toll would be less.

In the aftermath of 9/11, I am sure that there must be engineers somewhere considering the possibilities of a hostile impact loading on the Golden Gate Bridge. Because of its exposure to wind and seismic forces, the Bridge is probably well designed against the kind of lateral loads that might come from a bomb blast sufficiently small, or at some adequate remove. As a consequence, the problem might become one of keeping potential bombs far enough away from critical structural components (the two towers, the main cables, the two anchorages, the auxiliary cables, and the bridge girders, probably in that order). A military attack might provide enough warning to close the bridge and initiate countermeasures, but a stealth attack by land could use the Bridge roadway to access vulnerable features. Further, since the Bridge is an aerial, sight-seeing destination, attack from a private plane might not offer as much warning time as a more standard, military sortie.

Without trying to second-guess terrorists in a morbid way, the Bridge's principal weakness is probably in the material properties of the main cables—steel being particularly susceptible to heat and corrosion. While the ganged cables are statically determinant (enabling catastrophic failure at a single point) the redundant connections to the anchorage would require more points of attack, but correspondingly smaller explosions, and not all of the redundant connections would have to fail simultaneously (this type of failure analysis could be done by any of my upper-division engineering students). If engineers responsible for the Bridge are not currently thinking through potential attack scenarios, they obviously should be—in consultation with military engineers, who spend much more of their time trying to figure out how to efficiently blow things up, and how to patch battle damage.

For example, if a private plane loaded with jellied gasoline were to wrap itself around a cable support at the top of one tower, how much warning time would motorists have to vacate the Bridge? Should Highway Officials have a mechanism in place (do they?) to more or less instantaneously shut down the approaches (and how far away should vehicles be held)? How could fire retardants be efficiently placed at the site of combustion, or how might the heat of combustion be safely dissipated? If the ends of the Bridge were simultaneously blocked, could we safely evacuate motorists by static lines or gondola to the respective shores? Assuming that someone with a grudge will eventually want to attack an American landmark on the west coast, should we "mis-direct" them by heavily defending the Bridge (e.g., studding the bridge with anti-aircraft drones), while posting minimal defenses, and advertising the "cultural significance" of some other, attractive target (perhaps San Simeon, from the perspective of historic continuity)?

The point is that a military attack on the Golden Gate Bridge was *not* part of the original design, although it probably should have been (Orson Welles and military planners were certainly considering the possibility of an attack on U.S. soil). Today, there is no excuse for ignoring military/terrorist threats. In fact, since the Oklahoma City bombing, Federal buildings are now being designed to withstand internal blast loading (fairly simple, although perhaps counter-intuitive for someone habituated to thinking in terms of gravity loads).

As a profession, we have made progress in limiting the potential for our designs to further intentional killing. Although such killing is admittedly a bad thing, a determined killing is difficult to prevent. In the end, perhaps the current moral obligation of engineers is to prevent the easy deaths, while playing for time—enlarging the window for a timely response to developing threats. However, not all projects (the Golden Gate Bridge is a notable exception) retain the attention of engineers after their completion, so an exploration of dire contingencies needs to be a significant part of the project's initial conception.

Economic Displacement and the Loss of Human Life

In a finite world, the attraction of resources to one area will preclude their use in another. In the extreme, this polarizes wealth, and leaves behind pockets of marginalized humanity, incapable of realizing the life they desire. Such poverty is often accompanied by the loss of life—killing and otherwise—and the differential of wealth drives migration, taxing the typically minimal services available for new arrivals, and further decreasing the capacity of an abandoned homeland. In addition, indigenous inhabitants or early immigrants, if able to exercise sufficient power, will have an advantage over newcomers, and often use their advantage to exact privilege. In such an environment, the frustration of competing against unwarranted privilege might also motivate conflict resulting in the loss of life.

The history of California is rife with economic struggles between peoples and regions, and the Golden Gate Bridge was rightly seen as an economic stimulus to the North Bay counties (including Sonoma County, where I grew up). Under Anglo development, the location of San Francisco benefited from natural port facilities, an existing presidio/mission with support infrastructure, and access along El Camino Real to the lush, surrounding farmlands to the south, and southeast. But originally located as a potential redoubt at the end of a narrow, highly defensible peninsula, San Francisco was separated from the counties to the immediate north by the Golden Gate. As a consequence, commerce to the north was traditionally limited by the availability of ferry traffic within the Bay. North Bay counties were therefore more isolated, agrarian, and economically limited. The Golden Gate Bridge improved access, drew capital as well as wealthier inhabitants, and contributed to the gentrification of the locals (or their exodus farther inland, to less pricey chunks of real estate).

Prosperity in the North Bay counties—augmented by the Bridge—fostered an unwillingness on the part of local inhabitants to do the nasty, or toilsome bits of work. For example, while I was growing up in Santa Rosa (the early 1960s) the public schools did not start until the end of September. Ostensibly, this was to allow school children to aid in the harvest of local prunes and to a lesser extent, English walnuts (both of which involved retrieving product from the ground). Yet, by the time I was there, few locals availed themselves of this opportunity (I certainly did not, although I did work construction jobs during the summer).

Mechanized farm labor is perhaps the most traditionally dangerous, nonbelligerent occupation, and if accompanied by inadequate wages, is understandably rejected by people with other options. However, migrant farm labor (drawn from regions low on options) had been fairly well established by the time of the Great Depression. While the end of the 1960s saw a few locals—otherwise stretching time between meals on communes, such as Lou Gottlieb's Morningstar Ranch—embark on farm labor, the region's less desirable, agricultural jobs (as now, throughout much of the West) were typically taken by "part-year" transients from Latin America.

This was not a new phenomenon, and the 19th century saw waves of Asian emigration—some, such as the Chinese, being met with extreme violence (more than one Chinese was simply killed at the end of the harvest, to avoid the cost of a meager wage). The point is that from a global perspective, the North Bay counties were already extremely wealthy. The Golden Gate Bridge enhanced this, and so is reasonably seen to contribute—admittedly, in a limited way—to the initial misery of the attracted poor.

Globally, corporations concentrate wealth and exploit the unprotected—particularly where they can operate off the radar of the obliviously empowered. If Malaysian children are working in clandestine, sweat-shop conditions to fabricate sneakers, it is at least partially because some North Bay residents—from a position of relative affluence enhanced in a small way by the Bridge—choose to buy cheap footwear. Effort placed in the Third World producing export goods for the First World, gives the rank and file little of value, and detracts from the labor required to produce the food they need to eat, and the other goods that might stay and enhance the local quality of life. I do not know of an Irish Potato Famine in the works anywhere, but the potential mechanism is well understood. The Third World needs fewer "Hard Rock Café" T-shirts, and a larger percentage of its own resources, to develop local culture and a more satisfying lifestyle. "Trickle down" failed to work in our own (U.S.) democracy, and it certainly will not work where the receptacles of poverty are so much more ubiquitous and overwhelming.

The problem for engineers is that most of their projects require capital—ready capital being primarily available in the First World. Engineering projects generate economic growth, and so the rich get richer (and, in a zero-sum world, the poor get poorer). If there is a possible solution here, it might be in the kind of *pro bono* engineering work demonstrated by groups like Engineers Without Borders. It would be helpful if such groups received better funding, maybe by levying a surcharge on all engineering projects in the First World. This is not the enormous "great leap forward" it might first appear to be, since some countries (like Japan) levy a similar engineering surcharge to support things like research and development.

The contributions of the Golden Gate Bridge are admittedly minimal in terms of global economic impact, but we are not justified in assuming they pass unfelt. While the motivation for economic enhancement in the First World is not death in the Third World, the lack of intention, or even ignorance of negative impact, does not absolve us of moral responsibility. Death, attributable to economic disparity is at least *partially* a form of killing, as opposed to letting-die. If the culpability for economic suffering is widely distributed, then the zero-sum impact of regional economic enhancement should be considered as part of the engineering analysis, at least for large, First World projects such as the Golden Gate Bridge. I know of no significant attempt to account for the economic disparity associated with engineering projects, and this certainly was not included in the analysis for the Golden Gate Bridge.

The Accidental Loss of Animal Life

I suppose the intentional killing of animals on the Bridge is at least possible (as unimaginable as it is, there are probably individuals who find sport in squishing small animals into the pavement). But the economic growth fostered by the Golden Gate Bridge also meant more space dedicated to human activities, with a correspondingly smaller habitat available for indigenous species. With the encroachment of humans, some species were displaced by others (wild oats and Eucalyptus trees, for example, while alien, have done quite well in northern California). And according to a *replacement* utilitarian theory, 100 happy dogs are equivalent to 100 happy coyotes (although the coyotes might not agree).

Perhaps, from a moral perspective, the most significant problem generated from loss of animal life is the increase in road-kill. For the most part, people who die in traffic accidents make the decision (perhaps ill-informed) to get into a car. While it may go unspoken, it seems reasonable that drivers and passengers, who contribute to the problem of vehicles with a dangerous amount of momentum, implicitly assume a proportionate risk. Do we not always feel worse about a pedestrian or bicyclist hit by a car, as opposed to someone similarly mutilated when two or more cars collide? However, with regard to animals, they seem simply caught in the headlights. Some die instantly and some linger, just as with human traffic casualties—but in the absence of an implicitly accepted risk.

The prevailing attitude with nonfarm animals has always been that those near a road would either develop car-savvy, or would be killed. In the case of feral species, populations would normally diminish (as they might, subject to the sudden introduction of thousands of hungry predators) and the scope of suffering would naturally lessen. On the other hand, sufficiently prolific species like squirrels might simply continue at culled numbers equal to the available food supply. In either case, large, less prolific, nonscavenging populations could easily dwindle and become genetically unviable.

In the case of pets, road-kill was easy enough to replace from the roaming excess of un-neutered animals, and the new pets, if unfamiliar with the perils of traffic, were given a similarly small window to come to grips with the presence of speeding vehicles. While pet road-kill continues, I seem to see fewer mangled pets now than in my youth. Possibly there are fewer free-range specimens among the un-neutered, but (although this evidence is just anecdotal) perhaps we have become better about taking care of our most cherished animals.

While I am currently living in a rural, mountainous part of the Great Basin, I see a lot of feral road-kill, ranging from moose, elk, and mule deer; to the magpies squished *into* the moose, elk, or mule deer they were feeding on. In the 25 years that I have been in this area, I have had two vehicular encounters with mule deer (one became flustered and bolted head-first into the side of my parked car; and the other was head-to-head at 65 miles per hour, totaling my car as well as the deer).

The point is that when I moved to this area in 1985, I was told to watch for deer when their mountain feed became depleted (November through March), and the intent of the warning was to allow me to protect my *vehicle* rather than migrating deer. Hunters might bemoan the occasional road-kill with a nice rack—I have even seen the ignoble taking of coup (like elk eye-teeth) from an otherwise mangled carcass. But even with the massive, post-War addition of rurally-placed "National Defense" highways, no one was taking measures to limit the time a feral animal might spend in harm's way.

When I first arrived in the area, there still were range cattle and a number of "cattle-crossing" signs on lightly-used state roads—although one typically saw many more deer on the road than cows. But after I had been living in Utah for a decade or so, a newly completed section of I-40 near Jordanelle Dam was actually engineered for a deer-crossing, using cobbled terrain and fencing to channel the deer migration to a specific, well marked, and highly visible section of roadway. Such a limited application may or may not have saved any *actual* deer (there are still many opportunities to be run down on I-80, a few miles away) but it demonstrates the inkling of an admirable attitude.

The point is that while most humans are less concerned with animal life than human life, we need to recognize that engineering projects, like the Golden Gate Bridge, contribute to the death of a variety of living things, and that to a certain extent, living things—as moral patients—have a claim on us moral agents. As engineers, we should recognize this problem and provide proactive solutions (like engineered deer-crossings). Deer who lose their footing and fall off a cliff may succumb to accidental death; and deer shot by hunters may be killed; but deer who crumple to the side of a road do it from an insufficiently acknowledged engineering neglect.

Conclusions

Death is not the problem; we are all born owing the debt of death. The problem is meaningless death, and the aspect of killing (intentional, unintentional, or partially accidental) implies that someone knowingly or ignorantly dropped the ball—denying the value of life and the meaning of death. Death is supposed to be a *natural* end, at least aesthetically required by our natural beginning, the declining efficiency of our biological containment, as a semi-closed system, and the Second Law of Thermodynamics. But nonkilling is still a significant goal for the engineering profession, and except for the possible, indirect killing related to opportunity cost (born by the Third World for engineering projects designed to economically enhance the First World) engineering as a profession has contributed to a progressive attitude respectful of life. Even with the evils of economic disparity, Engineers Without Borders, as a 21st century organization, should certainly be seen as a positive step in the right direction. The problem is that we need to be careful to couch the requirements of nonkilling in an enabling way.

Elizabeth Anscombe (1981) made an interesting comment about pacifism between the two world wars. She held that a typical belief—professed by militant governments—was that pacifism, while noble, was beyond the reasonable expectation of existing regimes. While this categorical denial of a lofty goal is a little self-defeating (like denying hunger because there is no food in your mouth), Anscombe goes on to say that governments, thus self-absolved from nonkilling on practical grounds, took the "in-for-a-penny, in-for-a-pound" attitude. Since they could not be "noble" they felt no compunction to be "decent" (hence, neither side refrained from the indiscriminant bombing of civilian targets).

If engineers claim nonkilling as an absolute, professional goal, and if nonkilling is not within our zone of proximal development (to use Lev Vygotski's term) then the goal of non-killing might simply be dismissed as unobtainable. "Ought implies can"; and if the profession cannot achieve the nobility of nonkilling, at least some might feel absolved from the responsibility of maintaining a decent respect for life. To be absolved at one point, might be construed as a license to totally ignore one's moral responsibility (certainly, one's moral sensibility might be expected to erode).

Not too many years ago, engineering was simply a branch of the military, and I do not think we are very close to achieving *ahimsa*. Both engineering and the military are currently used to enhance or exact privileged status, and neither pays adequate attention to the holes they tear in our global fabric. Racism, nationalism, religious intolerance, and entrenched privilege are recalcitrant foes—feebly opposed by our efforts in the engineering curriculum, to address the problems of a nonkilling profession. I teach a class in engineering ethics to approximately 300 students a year—and consideration *here* is a miniscule step—but the moral dialogue needs to include active professionals. This is not something you can force with units of continuing professional education, and a serious dialogue may have to wait for the collective will to change. Perhaps volunteer organizations, like Engineers Without Borders will become so overwhelmingly successful that the profession as a whole will desire their institutional subsumption, and be willing to abandon the limited attitudes of centuries past.

A dialogue as to the goals of *ahimsa* might help us to appreciate the negative impact, on isolated individuals, of our otherwise positive projects. With appropriately respectful attitudes, the private good becomes the public good, and recognizing our moral obligation to marginalized victims is an important step. Thus, engineering concern for the individual, comparable to the concern expressed by physicians, seems to be at the core of a viable professional ethic for engineers. As engineers, we must consider the needs of all individuals, along with our first inquiries into the possibilities of engineered solutions in support of the public good.

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Moving Engineers Toward Nonkilling

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"Technology is an attitude of mind, not an assemblage of artefacts."

Chinua Achebe

Artisanship: A Path to Nonkilling?

Let us imagine a young girl who wishes to construct a small tower out of building blocks. It is easy to picture this girl as beginning with a predetermined plan before deciding what materials she will use. In her building process, she will perhaps use plastic toy blocks to build this tower. Initially though, the plastic blocks lack the form which she strives to give. The blocks are passive material that require orders or direction from something external, in this case, the girl's plan and guiding hand, to become an artifact. As Adams and Grooves (2007) would put it, the future of the blocks is inconsequential to the design of the girl as she cannot see the applicability or use of the blocks beyond her use. The blocks or their context do not have any value in themselves. Adam and Grooves state that such architectural thinking is the basis of industrial capitalist societies. In these societies, the production of artifacts is divorced from the material by which they are formed since only the efforts of the architect matter. This leads to the creation of artifacts divorced from their contexts socially, environmentally, materially, spiritually, etc. In the case above, the young architect is free to impose her plans onto the blocks without considering what the blocks are appropriate for and how they should be used.

The model of the architect is distinctly differentiated by Plato from that of the artisan, where the laborer is a passive source of labor to the object (Protevi, 2001). Plato suggests that an artisan, such as a stonemason or skilled carpenter, forms a shape through cooperation and reaction to the internal structure of the material unlike the architect who imposes his plans. This artisan skill, Plato claims, is a result of years of physical training rather than intellect and cannot be precisely planned. In other words, the artisan does not to try to impose a form on the material from the outside, but rather "strives to follow the salient traits it bears within it (such as knots of wood, twists of fibres, or the striations with marble) to which the intensive training he has undergone has made him sensitive" (Deleuze and Guattari, 1988: 380-382). This process of creating is therefore limited by both the artisan's capacity for involvement in the material and the nature of the material's resistance to the artisan's very involvement. The artisan acknowledges the limitations that nature and context impose on her work and, therefore, learns to cooperate rather than command and dictate the artifact that she strives to create. On the other hand, the architect "must possess the correct techne, a set of rules that can be set down and taught, and which consists largely of knowing how to command matter, using a measured process of division and allocation" (Adams and Grooves, 2007: 133) to create artifacts. Techne, Plato argues, is fundamentally rooted in commanding matter and imposing one's values (Protevi, 2001).

It is our assertion that engineers have created, and still create, artifacts using the architectural model described above. This means that engineers impose their values on artifacts they design without consideration of the context of the artifact. In fact, engineers have traditionally not viewed technologies as complex processes of mutual forming and shaping that operate across the inorganic, organic and human strata of the world (Adams and Grooves, 2007). Instead, engineers have designed in a hierarchical manner imposing their values on materials, processes, practices, and artifacts. Vanderburg (2001) documents this by illustrating a story of how engineers attempted to fix an overheated room caused by a faulty thermostat by opening and closing windows. In their mind, the thermostat should work regardless of its context, since other thermostats designed in a similar manner work! This hierarchical relationship to artifacts has led to much harm to our biosphere and our social relations. Instead of promoting predictability, reciprocity, and stability, engineers have designed technology that promotes social and environmental violence.

How then can engineers challenge this hierarchal relation to the inorganic objects? What can engineers learn from the artisan? How can engineers adopt the relationship of artisans to their work? More importantly, how can engineering ethics be impacted by artisan norms and practices that will allow for the nonkilling of the environment and the societies in which they operate?

The authors, who are both engineers, hereby propose the "artisan engineer" as a model to address the questions posed above. As we will discuss and hope to understand throughout this chapter, the artisan engineer must fulfill these requirements if nonkilling is to be promoted:

- the artisan engineer is an autonomous creator intimately connected to her local environment and community;

- the artisan engineer listens to the community for which they produce artifacts;
- the artisan engineer values not only technical knowledge but also an ideology that places artifacts solidly in the context of human needs.

As we will demonstrate in this chapter, it is essential that engineers establish a relationship to their artifacts and work similar to that of artisans in order to promote nonkilling in society and the environment. It is further argued in this chapter that engineers must challenge their current approach to work and creation of artifacts if they are to recognize and stop this violence. The model of artisanal work is one alternative to the architectural model of work practiced currently by engineers.

Definitions of Artisan

Drawing from Marx, Hanagan (1977) points to three definitions of artisan: as petty capitalist, as labor aristocrat, and as skilled autonomous worker. In the first perspective, artisans are considered to be part of the petty bourgeoisie since they profit not only from their labor but the labor of workers under them such as apprentices. In this particular view, artisans are seen as surplus profit producers. However, artisans may also be viewed as privileged workers set off from the rest of the worker population by the conditions of their work, their pay, their chance for advancement, etc (Hobsbawm, 1984). In other words, they are the aristocratic class of labor because of their privileged working conditions. Finally, artisans may be seen as skilled and independent workers, who control the production process. Hanagan (1977) argues that such an artisan is a worker who is highly skilled, possesses all the skills required to complete an artifact, and controls entry into his profession. In his study of the artisanat in post-1919 France, Zdatny (1990) similarly defines artisans as skilled workers who work for themselves, own their own tools, and participate personally in the complete production. It is this definition of the artisan that we work with for this chapter.

A Glimpse Into the History of Artisans

Before going on to describe the artisanal model of work, it would be instructive to glimpse into the history of artisanship in Europe and elsewhere. A full history of artisanship is beyond the scope of this chapter.

Artisans in the European context first arose in the independent kinship-based clans (*oikos*), where craftsmen produced goods just for their clans. This was paralleled with the rise of brotherhoods and guilds that were composed of independent craftsmen who created products that had exchange values. However, artisanship did not emerge as a distinct category of labor until the establishment of the Greek city-state or polis. In the polis, artisans engaged in distinct labor that contributed to trade and the material needs of the city. Even then, artisans worked independently beholden to no other economic or political interests other than their own (Koniordos, 2001). During the Roman Empire, artisans, organized in state-protected guilds centered in urban areas, continued to be economically and politically independent by being hired to produce certain work in their own way and in their own time. Despite their independence and self-sufficiency, artisans in both the Roman urban center and the Greek polis were low in social status and did not participate heavily in the civic life of their cities. This changed in Medieval Europe with the development of independent towns, which boasted specialized craft guilds each with its own structure, concerns, rules of membership, etc. Due to the importance of manufacturing in these town centers, artisans occupied important positions in society often backed by their guilds. The guilds further backed up their members by offering them regulation in their field and noncompetitive relationships with other artisans producing similar goods (Koniordos, 2001).

To join such guilds, artisans first had to apprentice with a master of the trade, who was a full member of their respective guild. Lasting several years, the apprenticeship consisted of the master teaching the newcomer secrets of the trade while he[1] worked for the master. During this period, the apprentice became proficient at all the tasks required for the creation of a finished artifact, while also gaining an appreciation of the intricacies of his craft (Farr, 2000). For example, an apprentice tailor in early 19th century England would not only learn how to make a trouser but also what kinds of trousers and for whom. In this way, the apprentice learned to have a holistic and thorough understanding of his craft and tools. He would also learn about the history of the craft and the particular ideologies of his profession. Other workers in his workshop would tell him about major workers' strikes in the past while the master impressed upon him the importance of worker autonomy (Eisemberg, 1991). This apprenticeship period was often followed by an examination by masters to test the competency of the apprentice or a period of being a traveling artisan before full entry into the guild, but this was not always the

[1] The male gender is used when referring to artisans and apprentices in this Chapter to reflect the overwhelming male history of the artisan profession both inside and outside the European context.

case (Koniordos, 2001). Once the apprentice became a master, he was considered to be an equal in the artisan community differentiated only by the skill of his craft. Of course, the path to becoming a master was often difficult, beset by the use of apprentices as cheap labor by masters and a violent masculinity in the profession that looked up to discipline (Herzfeld, 2004).

This all changed with the advent of industrialization and market economies. Artisans became insignificant in the new market economy as they could not compete with mass manufacturing and increasing division of labor. Guilds reacted by imposing restrictive rules on their members to limit competition, which ironically made artisans even less able to compete in the new economy. Flouting these restrictions, some of the wealthier masters hired more apprentice craftsmen outside of the approval of the guild seeking to meet the demands of greater production. This process was coupled with merchants funding many apprentice or journey artisans under a "putting-out" system. In this putting-out system, the merchants would fund the artisans hoping for a profit from their work. These funders (both master-artisans and merchants) gradually shifted from not just providing financial support to their employees but also dictating the work process (Koniordos, 2001). To meet the demands of production, greater division of labor and control of the work process was encouraged by the funders. Unlike the past, each artisan was no longer in control of the complete product. The work was divided into distinct and replicable steps. Eventually, machines were developed that could perform these steps and placed in a factory with other machines (Wallace and Kalleberg, 1982). In this way, artisans in Europe who had enjoyed centuries of independent and holistic control of their work became reduced to unskilled laborers.

Meanwhile in mid-18th century India, many artisans still belonged to hereditary castes that mainly created artifacts for social needs within their community or for subsistence level production (Kealey, 1976). These artisans were intimately connected with their communities through their work. In return for a share of the village produce or some other arrangement (rent-free land), they produced material goods for their community such as houses and pottery. Like their European counterparts, these artisans were independent workers beholden only to the needs of their clients. However with the development of the market and with the erosion of traditional guarantees to artisans (i.e., rent-free land), many artisans moved to large commercial centers that created distinct goods for the market. For example in the province of Bengal, almost every city and rural town had people that engaged in only textile work for domestic and international consumption. This made it easier for merchants and companies to gain control over the means and methods of production of these artisans as they controlled the input of resources and the output of goods into the market. Eventually, rising debt and increasing division of labor led many Indian artisans to give up any control they had over their own work and, therefore, any connections they had to their communities (Kumar, Raychaudhuri and Desai, 1983).

African metallurgists were already practicing artisanal (autonomous, community-grounded) metal work probably as early as 500 B.C.E. but definitely by the sixth century in Nubia, the 8th century in Egypt, and the ninth century in North Africa (Childs and Killick, 1993). These metallurgists smelted iron and copper products for trade with other communities near them, for currency, for material use (tools for agriculture), and even for religious purposes (as grave goods). In fact, the whole arti-fact creation process was intimately linked with the spiritual and supernatural life of the artisans and their respective communities. Some artisans even acted as sorcerers and shamans crafting protective amulets for their clients (id.). The smelting was undertaken far away from settlements by specialized and trained individuals. These artisans were trained through an apprenticeship, similar to the apprentice model in many other parts of the world. For the most part, metallurgists were permanent residents of one village and often worked only part time. However, in more economically and politically stratified societies, artisans were a distinct class of full-time workers (id.). With the arrival of the Europeans and cheap European goods, the demand for local specialized metal artifacts decreased. After World War I, most of the iron smelters and other indigenous furnaces were shut down.

In 19th century Shanghai, guilds were important elements directing both the social and economic life of artisans (Protevi, 2001). These guilds were not only tied to a specific trade but also to a specific region. More so than their European counterparts, Chinese guilds were politically powerful and relevant, often banding together artisans to make demands. Some guilds were even able to guarantee working conditions such as a nine-hour workday for their members. The strength of the guilds and the tradition of communal resistance helped artisans adapt to modernization and the factory system. The guilds also played important roles in other aspects of artisan life. Artisans were educated in their trades through recruitment into their guild where a master took them under his wing for three years (id.). However, recruitment was not open to all. Apprentices were often expected to come from a specific region and pedigree/connections were important. Once the apprentice was admitted into the guild though, he entered a closed world where he spent most of his work and social time with his fellow guild members.

While today surviving artisans are forced to either accept "their role as the picturesque bearers of an obsolescent tradition" or join "an international labor force in which the price of modernity is to lose one's identity as a skilled and individual personality" (Herzfeld, 2004: 60), some do still earn a living as independent artisans. Furniture makers in Lugang, Taiwan still work independently and on their own time. In fact, most of the nineteen artisan workshops in Lugang during the study by DeGlopper (1979) were owned by extended family networks and all were selling their products through direct contact with clients. Apprentices at these workshops still worked on one product from start to finish customizing it for their customers. In addition, each one was concerned with creating the best quality product, as an inferior product would hurt the standing of the workshop in the community. In one instance, an artisan building an altar table for a temple had customized the table according to the requests of the temple committee and the proportions of the room in which the table was to be placed. This shows that the tradition of contextualization in artisanship was still alive and well. The altar table because it was created by an artisan and not an assembly line would be ideally suited to the context of a particular room in a particular temple. Modern production techniques are not suited for this contextualization of artifacts. Unfortunately, most artisans working today, especially those in the Global South, suffer from having to engage in unskilled work to produce mass consumed goods in a global marketplace that leaves them in increasingly vulnerable positions (Scrase, 2003).

The Relationship of Artisans to Their Work and Creations

Artisans in India, Europe, China, and North Africa have distinctive histories with different practices, customs, and goals. However, their relationships to work and their artifacts have some general themes in common. Drawing from our definition of an artisan, we argue that artisans:

- valued autonomy in their work including the independence to decide what work to do and how to do it;
- had control over the entire process of creating an artifact from start to finish even if apprentices contributed labor;
- created artifacts within a local environmental and social context;
- were intimately connected to their community of clients through reciprocity.

These themes, of course, varied according to time, place, and socioeconomic conditions. In some economic settings and cultural contexts, artisans did not have complete autonomy since capital could have been provided by an external party or if artisans were beholden to a certain political class. In other contexts, artisans did not have full control over production or intimate connections with the community. Even in cases where the artisan community followed these themes in general, there were artisans who fell outside the norms of their profession. Generally speaking though, these were themes or values found in pre-industrial artisinal production. As we argue in the next section, they served as important checks for artisans in the creation of nonoppressive artifacts.

Valuing Autonomy

An autonomous worker as defined by Soffer is a worker who has a degree of control "over the quantity and quality of production; the choice and maintenance of equipment; the methods of wage payment and determination of individual wages and hours; the scheduling and assignment of work; recruitment, hiring, layoff and transfer; training and promotion of personnel; other related conditions of work" (Soffer, 1960: 141). This is certainly the case with artisans. Artisans as producers of artifacts have traditionally had the autonomy to decide if and how work should be done to produce that artifact. In pre-1914 United States, craftsmen such as potters, iron workers, and newspaper printers were all autonomous workers either because of the skilled nature of their work, difficulty of supervision, or the lack of interest from capital holders (Soffer, 1960). For example, the iron rollers of Columbus Iron Works in Ohio, United States decided on how work would be allocated, how much work would be done, and by whom without any external interference (Montgomery, 1980). Artisans in mid-1800s Philadelphia even dictated whether they would work on certain days (Laurie, 1974). It was not unusual for these workers to take the day off to go hunting, to take part in neighborhood sporting activities, or to have a drink. Many working Mondays were lost as a result. Blewett describes how preindustrial shoe production in New England was carried out by artisans who had full control of the process before merchants came to supply the materials and demands to artisans (Blewett, 1983).

This was also certainly the case in the urban areas of Europe, where masters, journeymen (traveling artisans), and apprentices all came together in complex networks to produce goods in autonomous shops (Safley and Rosenband, 1993). The goal of this type of economy was not to maximize profits or growth but to provide full employment for workers while ensuring worker autonomy (Farr, 2000). In his shop, the master artisan was free to decide if and how work should be done although that type of autonomy decreased downwards in the artisan hierarchy. This autonomy was possible because the skill and knowledge of the master-artisan could not duplicate without years of study in the "mystery" of the craft. In addition, the particular work required by the artisan's craft cultivated a craft-consciousness and group consciousness within the artisan community that led to fierce independence (Safley and Rosenband, 1993). In fact, the shop itself was an autonomous unit that ran according to the needs of the master-artisan and the shop workers. This was possible because the master-artisan and his shop could access the local market to sell their goods. They did not need to depend on a merchant or middle-man to sell their goods as happened later with the rise of industrialization and capitalism (id.).

Once this happened, the autonomous craftsman became shackled to the needs of the market and his funders. The merchant with capital or the middleman with access to the markets could dictate production. While the rise of industrialization led to devaluation in the work of most 18th century European artisans, some were able to protect their autonomy by adapting technology for their use. For example, the spinning jenny, before being adapted to factory use by making it steam-driven, was adopted by cottagers by word of mouth. Each cottager would make his version of the spinning jenny to be used in their own shops. In this way, the machine was used by each cottager to increase their output without losing their autonomy for over ten years before the jenny was ever placed in a factory (Reddy, 1984). Other artisans attempted to protect their autonomy by staging work stoppages such as strikes, demonstrations and riots (Montgomery, 1980).

The value placed on autonomy by European artisans can also be seen in the education of the apprentices. In Medieval Europe, apprentices were not only taught practical skills during their training, but also the customs, traditions, and ways of life associated with their particular craft (Koniordos, 2001). It was the goal of master artisans to impart a sense of independence and pride to the apprentice through teaching craft history, so that the autonomy of future artisans in that trade would be assured. The apprenticeship system was not just exclusive to Medieval Europe. It was practiced in the workshops of West African artisans as well (Osborn, 2009). As with their European counterparts, African master-artisans communicated skills, ideology, and a sense of independence to their apprentices.

Fortunately, industrialization has not completely wiped out artisan production. More recently, Sinha describes the production process of potters in western Massachusetts in the U.S. (Sinha, 1979). Through that process, she shows how the potters control all aspects of production from choosing which clay to shape to deciding at which fairs their goods will be presented. Although autonomy of work increases as the potter gains recognition and experience, even beginning potters have some autonomy over their work even if they are more dictated by the demands of their clients and the market.

Holistic Production

Ursula Franklin differentiates between holistic and prescriptive production of artifacts (Franklin, 2004). For her, holistic production happens when one individual creates an entire artifact from start to finish. In contrast, this same individual may only be responsible for one part of the creation of an artifact in prescriptive production. For example, a potter working holistically will have control over the entire production of the pot, from which clay to use to where the pot may be sold (or not sold). Meanwhile, a potter working prescriptively may only be responsible for firing the pot and not selecting the material of the pot or for shaping it. Other potters or, more likely, the manager of the potter may control production. Since holistic production is linked to having control over production, worker autonomy and holistic technologies are intimately linked together.

While the artisan has traditionally worked with others, whether in a guild or in a cooperative, the production of artifacts has remained completely under the control of the individual master-artisan. He is able to control how the artifact is created, in what ways, and for what purpose. Therefore, the same artifact might be created differently each time as the artisan is free to change the production process (Simon, 1998). The independent nature of artisan work allows artisans to decide on which values should be embodied in their creations. After all, an artisan is not simply a creator of artifacts who knows how to shape, modify, or use material. Rather, the artisan uses materials to embody his values and the values of his society. For example, a potter does not simply patch together certain materials but starts with a "conception in mind about the purpose to be served by a pot, a feel for his materials, and a sense of proportion about what constitutes a good pot" (Ostrom, 1980: 309). In this way, an artisan thinks holistically when creating new work. No decision about the created artifact is made in a vacuum.

For example in Sinha's (1979) study of potters in the United States, all of the potters craft a product from start to finish. As they gain experience, potters alter the way in which they make pots to add variety to their products and potentially increase their profits. However, it is the individual potter's decision to change his pots or the way in which he makes them. This tradition of holistic work is not just restricted to European or North American contexts. South

Indian artisans from the Visvakarma caste of Karnataka subscribe to a religious ideology that places great importance on completeness and autonomy (Brouwer, 1977). For them, an artifact is not complete until the user of the artifact summons them to complete the artifact just before use. For example, an artisan may create a necklace to give to a patron, but the patron will not use the necklace until the artisan can be summoned to attend a ceremony that "completes" the necklace. In this case, artisans not only create a complete artifact but also have a say in when their artifacts are to be used.

Working Within a Local Context

We argue that just as autonomy and holistic production are connected, so is local context and holistic production. If an artisan is to create a complete artifact, that creation must take place within the social and environment context of the artisan. The artifact cannot simply be made in a vacuum. It must necessarily be connected in some way to serving the needs of the artisan or the artifact user or the client community. The description by Walker and Seeman of how Indigenous Australian women created baskets shows just how closely artisan labor and environmental/social context were historically linked together.

Traditional knowledge has sustained the existence of indigenous Australian cultures for over 60,000 years. Technology and technical activity were inseparable from social and environmental knowledge. There was no framework for practicing technical knowledge apart from social and environmental knowledge. To produce an artifact, a tool or a shelter was to integrate all three forms of knowledge. To illustrate this point consider how women in small island communities in northern Australia integrate skills to produce pandanus baskets (or carry bags) for themselves. They organize a work group, with each woman having particular tasks, including food preparation and child care. They arrange transportation to a site in the natural bush to harvest the best pandanus trees. Each tree requires a keen, informed eye to pluck the better leaves for weaving. Roots also are collected for dye. While this is going on, children are encouraged to watch carefully as a learning exercise, not only in pandanus harvesting but equally in the social protocols and organization of the whole day. Some of the tools for manufacture of the baskets are fashioned by the women themselves while others are purchased (Seemann, 2009: 122).

Similarly, Smith (2004) points out that European artisans in the fifteenth and early sixteenth century valued working with nature around them. European apprentice artisans during this time period were not only taught to observe and represent nature but also to intimately understand the natural materials they worked with. Their [artisan] epistemology, as articulated in texts, in conversations with scholars and their patrons, and in naturalistic works of art, suggested that direct access to nature was both possible and necessary, that knowledge was gained through bodily engagement with matter, that "scientific" knowledge (in Aristotle's sense of *scientia*) could be extracted from nature, and that the imitation of nature yielded productive knowledge (Smith, 2004: 20). These European artisans were connected to a local environmental context intimately through their years of studying nature during apprenticeship but also when they created artifacts. Like Plato's artisan, they could follow the individual knots in a piece of wood.

In more recent times, the practices of potters in northern Cameroon show the intimate links between artisans and their social/environmental context. These potters have different techniques for processing clay based on the differences in the clay sources near their communities and their membership in a particular ethnic/linguistic group (Smith, 2000). All of the potters know where certain types of clay are available, how to process them, and what they are suited for creating. This knowledge was gained through participating in learning networks based on membership within particular ethno-linguistic groups. In other words, the craft of pottery for these artisans was restricted by their environmental and social context. They would not or could not create pottery using clay not suited for their local environmental and social context.

Other West African artisans have also proudly taken up the tradition of working with their environmental and social context. As more and more aluminum scrap was deposited in African junkyards in the mid-1900s, artisans began to adopt the metal for use because of its availability and reuse qualities (Osborn, 2009). The metal was ideally suited to the West African context because of its ability to be shaped using low energy requirements and a native shaping process (sand-blasting). More importantly, this metal was available extensively in the environment as opposed to copper or gold. These artisans, by using aluminum, are cleaning up their communities and reusing scrap.

Artisans may even create artifacts that are situated in their personal lives. Women handcrafting textiles in the region of St. Louis, United States create artifacts that are not just connected to their local context but also their personal histories (Johnson and Wilson, 2005). These artifacts are sometimes given to members of their family or close friends. They hold meaning not only for the receivers of these artifacts but also the women creating them. In this case, artifacts are not just rooted in the social context of a broad community but a small community of love that is defined by the artisans.

Reciprocity

The final common characteristic of artisan labor, we argue, is the open relationship between artisans and artifact users that is created through shared experiences and common daily living. This relationship allows artifact users to provide meaningful reciprocal feedback to artisans. In fact, artisans must accept and integrate this feedback into their work if they are to be successful at distributing their artifacts whether in the market or through the community. Ursula Franklin (2004) defines "reciprocity" as feedback that is not designed into the system or anticipated. Rather, reciprocity, unlike other forms of feedback, should critique the assumptions of a system or created artifact. It differs from other forms of feedback because it doesn't simply seek to improve a system or artifact.

Artisans invited reciprocal feedback because their labor was not merely an economic act but also a social act connected with the needs of their commuity. The labor provided to the community by the artisan insured his prosperity and social standing in the community (Schultz, 1990). If that labor was not appreciated by the community, the artisan could not prosper. Gramajo (2006) writes about the importance of social capital and reciprocity for the Wayúu artisans of the Guajira Peninsula of Colombia. These weavers rely on social capital built from trust and reciprocity to distribute and sell their crafts. If their clients cannot rely on them or if they are not open to reciprocal feedback from clients, they risk losing customers. Since much of their goods are sold locally on credit, the Wayúu weavers take great care to cultivate relationships with clients establishing both their trustworthiness and openness to feedback. In fact, craft production in eighty percent of all Wayúu workshops happens only if a client asks for a specific order. In this way, clients have a say in the crafts that are produced.

This reciprocity can also be seen in the way artisan guilds set prices for their products in medieval Europe. Koniordos (2001) states that conceptions of fairness held by medieval European artisans were shaped by daily life in their communities. A "just price" was determined not through supply and demand but through knowing fair pricing in a community. The artisan, as a member of the community, knew how other goods were priced, what customers were willing to pay, and the prices set by local competition. If this price was not fair, clients would let the guild, which regulated the prices, know that such pricing was beyond their reach. Reciprocity also applied to the suppliers of the artisan's materials. If securing the necessary resources to produce the artifact came at an environmental or human cost to the community in which the artisan operates, the artisan would be motivated due to their intimate connection with their community to change suppliers or switch to materials that would not damage the ecosystem of the community.

Artisan Values and Nonkilling

Nonkilling, as defined by Paige (2009 [2002]), refers to the absence of killing, threats of killing or conditions condusive to lethality toward humans and nature. Conditions that promote nonkilling are conditions that remove the social, ecological, economic, spiritual, and technical causes of lethality. Compared to nonviolence, nonkilling takes a more direct approach toward removing or minimizing the factors that promote killing. In other words, if nonviolence attempts to address violence at a superficial level, or the symptoms, of a much deeper dilemma, nonkilling attempts to tackle the dilemma at the roots. However, the concepts of nonkilling and nonviolence are very much related. In this section, we argue that artisan values play an important role in the promotion of nonkilling and that the absence of these values leads to killing.

Again, the four values associated with artisinal work are autonomy of work, holistic production, local contextualization, and reciprocity. We argue that such values promote nonkilling, i.e., the removal of killing and conditions condusive to violence and lethality. In particular, these values address five different forms of violence.

The violence of the workplace: Violence in a hierarchical workplace is both physical and social. It arises when workers and management do not share values. Workers may be directed by management to work in unsafe and unhealthy working conditions in order to maximize profit. This is the case in many assembly lines, where it is not uncommon for workers to suffer from a workplace injury. However, workplace violence can also be social. Workers who do not wish to produce a certain product or wish to protest working conditions may suffer from retaliation from their employers. This retaliation can result in the loss of employment or lack of promotion.

The violence of nonaccountability: If workers cannot be held accountable for the artifacts they produce and the ways in which they produce, then they will not feel any responsibility for their work. Without accountability, workers could produce artifacts that promote violence or result in deaths or employ violence and lethality in their production (toward the environment or people) without any repercussions.

The violence of technology-based connectedness: Vanderburg (2005) writes extensively about the replacement of culture-based connectedness with a more violent technology-based connectedness. Technology-based connectedness seeks to supplant the cultural and social norms of a community with a foreign technological logic that previously had no basis in the community. This leads to a loss of the shared cultural values and symbols that keep communities together.

The violence of alienation: Alienation is one result of the loss of culture-based connections. It is a form of social violence that has been discussed by Marx among others. Marx (1959 [1844]) argues that alienation in people occurs when they are separated from aspects of their humanity. The violence of alienation may result in people believing that they are a commodity in a large system or a "cog in the machine." This results in feelings of powerlessness and despair. At worst, alienation may result in the oppression of others as happened during the Holocaust as a common sense of humanity is lost (Bauman, 1989).

The violence of imposed values: This is the violence of imposing values foreign to a community through unilateral action. This form of violence is often backed up by a sense of superiority on the part of those who wish to impose their values.

Perhaps the most important of all four artisan values in this discussion is the autonomy of an artisan worker. While the other values promote nonkilling on their own, autonomy of work not only promotes nonkilling but also enables the other three values. Autonomy grants the artisan agency to holistically create, understand their context, and listen to their clients. Without autonomy, artisans are not truly free to make decisions about their artifacts. For example, an external funder interested in maximizing profit may dictate production, in which case, an artifact would not necessarily be created holistically or with the host community in mind. Instead, the artifact would be created with the priorities of the funder in mind such as maximizing profit. Therefore, autonomy is a prerequisite for artisans in making meaningful decisions about their work. This was recognized by proponents of the Swadeshi (self-sufficiency) movement in India. The goal of the movement was to encourage Indian consumers to buy Indian goods produced by Indians, so that the economic hegemony of British rule could be broken (Giri, 2004). It was part of the greater struggle for Indian self-rule championed by the great practitioner of nonviolence, Mahatma Gandhi. Gandhi and other supporters of the Swadeshi movement realized that the only way to break British control over production was to encourage indigenous production over which Indians would have control. Autonomy played a central role in this struggle as it was exactly the autonomy of the Indian producer and consumer that proponents of Swadeshi wanted to promote. Without autonomous producers of Indian goods, the British would always maintain their economic control over India.

However, autonomy also limits the violence of the employer on the employed. Using the example of the external funder from above, let us assume that the artisan does not wish to create the profit-generating artifact. If the artisan has the autonomy to dictate production, there is no problem. The artisan can simply follow her desire. If, however, the artisan does not have autonomy, the artisan could be ordered (politically through laws and social norms or economically through withholding of capital) by the funder to create an artifact that promotes communal and environmental violence but generates high profit. This would be done not necessarily through physical violence but social violence. In our industrial context, lack of autonomy leads to violent working conditions that breed killing of the mind, body, and soul. Workers on assembly lines have to deal with working in dangerous conditions where they have no say in how fast the assembly line runs for little pay and job security (Linhart, 1981). On the assembly line, they are exploited, victimized, and robbed of their dignity. Some of them are not even allowed to talk to each other in the factory or step outside their cramped standing workspace. They have no autonomy over their work, so they can, at best, only demand changes in their working conditions, which are usually just ignored. If these workers were autonomous, they could simply make the desired changes in the working conditions.

More than that though, autonomy asserts the artisans' responsibility for their artifact even after it has left the workshop for daily use. Since the artisan has wholly shaped the artifact, she and no one else is responsible for any violence that may be embedded into the nature or use of the artifact. Even if a customer uses the artifact to kill in a way not intended by the craftworker, she is partly responsible for designing the artifact in a way that enables it to be used for violence. If a client uses a steel ornamental spear to cause harm, the artisan who created the spear is responsible for enabling this function of the spear even if the intention was to create a decoration piece. Instead, the artisan could have used a different material to blunt (if not remove) the harming potential of the spear. In this way, autonomy forces artisans to bear the responsibility of any negative impacts their artifacts may produce. On the other hand, lack of autonomy leads to a loss of responsibility as well. Workers on an assembly line can hardly be held accountable for the artifacts they produce. Only an autonomous worker is truly accountable for the artifact they produce.

Considering how an artifact may be used is one part of holistic production. As we discussed earlier, holistic production as opposed to piece-meal production is interested in the entire production life cycle of the artefact, not just one step. The use of an artifact is part of the entire life cycle of an artifact. We believe that holistic production promotes nonkilling as it reinforces the responsibility of the artisan over her work. Since the artisan is wholly responsible for creating her artifact, she can be held accountable for any harmful or violent effects caused by her work. Again, this responsibility can be shared by the user of the artifact, but the artisan is still responsible for the potential uses of the artifacts and its nature. In addition, this responsibility is not just limited to immediate production of the artifact or its use. Rather, the responsibility extends to every aspect of production from where materials are obtained and in what manner to what type of labor is used to help with production. An artisan is accountable in all of these decisions because she has the agency to make them. For example, an artisan promotes violence if their clay pottery is produced by indentured laborers or if their "environmentally friendly" rechargeable batteries are created by materials mined in a war zone. In this way, artisans are accountable for every stage of production. Without holistic production, responsibility may be passed on to other actors in the production process. Engineers involved in the production of cell phones use coltan, or rather a refined form of coltan called tantalum, which is mined in the Democratic Republic of Congo. The trade that developed around the mining and selling of coltan has provided substantial funding for a bloody civil war in the Congo, which has led to environmental destruction and the loss of human life (Essick, 2001). Yet global demand for coltan and tantalum has increased because of increasing demand for the electronics that use these materials. The firms that employ these engineers like Nokia have simply said that it is not their responsibility to insure that tantalum comes from nonconflict sources. They, and the engineers they employ, have simply passed on the responsibility to their tantalum suppliers, who have passed on the responsibilities to their suppliers and so on. Since no one is actually completely in charge of making a single cell phone from start to finish, no one can be held accountable.

If the autonomy of artisan workers allows them to practice holistic production, then the result of these two values is contextualization of artifacts. As we argued earlier, holistic production does not take place in a vacuum. The artisan is not merely making a part but a whole that has certain functions, aesthetics, and embedded values. Artifact creation must necessarily take place in a certain social, economic, spiritual, and environmental context as the artisan is concerned with shaping the artifact to serve the needs of her clients. It is this shaping of the artifact to fit the user's context that limits killing of the environment. By using appropriate natural resources and understanding the environment of the artifact user, artisans can limit damage to the environment. Instead of using wood from an endangered tree species in the region, an artisan, who understands her local context, would use wood from a tree species that is more readily available. In this case, contextualizing an artifact leads the artisan to not disturb the equilibrium of her ecosystem. In another example, an architect could design buildings in hot and windy climates with open spaces and flexible architecture to allow for both cooling and structural strength (Hyde, 2000). However, if the architect used an existing building plan from a building in Canada, the buildings would be highly inappropriate for the climate and would require artificial cooling. This would cause a major negative environmental impact. In other words, thinking of context allows this architect to work with nature instead of imposing on it.

Contextualization not only promotes a nonkilling attitude toward the natural environment but also protects social/cultural networks. If an artisan designs with her and her client's social context in mind, the resulting artifact would strengthen existing cultural and social connections instead of eroding them. This is important for nonkilling because cultural/social connections or culture-based connectedness prevents violence by enabling people to share values in a community. Culture-based connectedness then is the sum of connections between people and their surroundings in their daily lives (Vanderburg, 2005). This connectedness gives meaning and direction to the members of the connected community through shared experiences and values. Without this connectedness, a community risks collapse as shared values are lost and each of its members becomes alienated from each other. Therefore in designing with culture-based connectedness, artisans promote nonkilling as these connections keep people away from the violence of alienation and isolation. Contextualization of artifacts, we argue, is one way to favor culture-based connections since an artifact must be shaped to fit into a cultural context. It cannot simply be left to its own technological logic. The field of appropriate technology is a good example of how culture-based connectedness is strengthened when artifacts are shaped for their users' context. Appropriate technology is technology that causes little cultural disruption by fitting into the social, cultural, economic, spiritual, and political modes of a community (Hazeltine and Bull, 2003). For example if a community has a large labor population, a technology that is labor-intensive would be more appropriate for that community than a capital-intensive technology. In this way, technology is working to benefit the community instead of disrupting it by increasing unemployment (a condition that promotes violence).

Determining whether a technology is appropriate cannot be done without allowing for reciprocity from the user community. Reciprocity, as we discussed earlier, is meaningful feedback that may challenge the assumptions of the artifact creator. Unlike other feedback which seeks to improve performance of an artifact, reciprocal feedback questions the nature of and need for the artifact. It limits the unilateral imposition of values and assumptions by the artisan on their clients since artifact users to have a say in the values of their artifacts. Not only does this preserve culture-based connectedness, but also limits the violence of imposed foreign values. At the same time, reciprocity encourages a dialogue within a community about the values of their artifacts. Without this dialogue, artifact users risk giving in to the violence of alienation and isolation that artifacts without shared values will create. Television is a great example of an artifact that creates alienation among its users because it does not allow for reciprocal feedback (Franklin, 2004). Since it is a one-way medium, television can only impose values on users. Users of television never have a chance to discuss the values promoted by television, the content which is broadcasted, or whether television is an appropriate technology for their community.

Engineers and Their Relationship to Work

Engineers have a decidedly different relationship to their work than artisans. Unlike artisans, engineers are not autonomous workers. Rather, they work in a culture of command and hierarchy. Donna Riley (2008) has written about the authoritarian culture of engineering, which has its roots in military and corporate cultures. Riley uses Crombie's analysis of megamachines, technologies focused on establishing centralized control, to explain how military and corporate organizations produced a set of engineering work values that are guided away from what is considered to be related to peace and social justice, "in particular, those that sustain and enhance life" (2008: 70). In another related example, Riley uses engineering textbooks to point to the close relationship of engineering culture with hierarchical and authoritative work. In particular, a quoted passage in a thermodynamic textbook associates low entropy to an organized army and high entropy to a disorganized one. The culture of command and hierarchy in engineering is, at the current moment, inescapable in their work. In fact, many engineers are politically inclined to follow authority at all costs even if those actions take away their autonomy (Riley, 2008). Vesilind (2005) goes as far as to say that engineers have traditionally given up their autonomy to serve as mercenaries for the rich and powerful. Without autonomy, engineers have to use their skills for corporate or military interests, which are often (if not always) antithetical to nonkilling.

Even if an engineer wished to protest the use of her skills for violent purposes (developing weapons for example), she would have no means to control the work she does in her corporate or military setting.

It makes sense then that engineers would also not be holistic creators of technology. Since they do not have control over their work, many engineers work prescriptively for their employers. Most of them work for large firms and have narrow skill sets suited to designing in one particular field (Stark, 1980). While one engineer may create one part of the product, another engineer would have to create the other parts. In the end, neither would be responsible for the social and environmental effects of the final product nor would they be able to question the production of the particular artifact. If an engineer questioned too much, they could easily be replaced by another engineer, since production is not dependent on anyone. This breeds the culture of compliance in engineering, which has led to the development of more and more violent military and profit-extracting technologies.

As for contextualization of technologies, the engineering curriculum has historically ignored any efforts to place engineering work in context (Johnston, Lee and McGregor, 1996). Engineers are told that the authority of science is absolute and universal. A scientific law that works in one place and time will work in all places and time. Therefore, their artifacts, which are based on scientific law, will work in the same way with the same results regardless of context. Context simply does not matter in engineering culture. At the same time, engineers are taught that culture or alternate understandings of nature do not matter. Drawing much from positivism without being aware of it, engineers believe that only what can be scientifically verified matters. Culture and non-scientific understandings of nature cannot be scientifically verified. It is this belief in the lack of context and the dismissal of culture that has led to engineers creating technology that pollutes our oceans and poison our skies.

In keeping with the trend of artisan values being absent in engineering work, reciprocity is also a missing theme. Engineers typically design technology without the input of users of the technology or the impacted community (Sclove, 1995). They typically do not ask for feedback either, but if they do, it is not reciprocal feedback. Those affected by the technology do not have a chance to challenge the assumptions of engineers. In Canada, engineers may hold public consultation for public works projects but, again, impacted communities only have the chance to improve the project. They cannot challenge the existence of the project. The lack of reciprocity in engineering projects has broad implications for engineers because it forces us to ask who engineers are designing for.

The Nonkilling Artisan Engineer

How can engineers ensure nonkilling in their work and produced artifacts? One way we have discussed so far is to adopt the work values of artisans. By becoming autonomous workers that create holistically and in a context while allowing for reciprocity, engineers can promote nonkilling in their communities.

While the individual engineer can implement these values at a local level, admittedly with significant difficulty and barriers, the broader cultural promotion of the artisan engineer as a counterpoint to the classical industrialist and corporate engineer would require a more collective effort. The first part of this effort must be to regain autonomy. We believe that engineers can reclaim autonomy through guilds and, their modern counterparts, unions. Guilds, at least in the European context, were crucial in preserving artisan autonomy. They protected their members from economic competition, preserved the political autonomy of workers by representing their interests to the state, and even served as mutual aid societies. In the Netherlands, artisan guilds offered social insurance such as an old-age pension plan (Reininghaus, 2002). While concern for the well-being of guild members surely motivated such mutual aid, it was also tied to preservation of autonomy from the state and the merchant class. If guild members did not have to rely on the state or private business outside their guild in their old-age, they would not be beholden to their interests either. These medieval guilds were supplanted by unions in some capacities. In the 1800s in Canada, coopers were organized under the Coopers International Union, which protected their work autonomy through collective action. With their union, coopers regulated their shops and entry into the profession (Kealey, 1976). Engineers today could similarly organize in unions and guilds to protect their autonomy as workers who are able to make independent and ethically autonomous decisions. The professional societies that engineers currently belong to like the IEEE are not a replacement for unions. They do not protect worker rights, wages, benefits, and autonomy. Many of them, in fact, do not make any efforts to protect their members from management or enforce worker protection rules like whistleblower protection (Herkert, 2001).

A drastic shift in the culture of engineering education also needs to occur in parallel. As mentioned previously, Riley (2008) has shown that military and corporate cultures permeate engineering education. This type of culture encourages both reductionist thinking that does not take diversity or context into account and giving away of autonomy. One way to counter reductionism in the culture of engineering education then is to use, as George Catalano

(2006) suggests, the ideas of complexity, interdependence, and systems thinking in Johnson's "morally deep world." If engineering students are taught engineering from the perspective of a complex and diverse ecology of ideas and practices, they are more likely to recognize the importance of diversity and contextualization in their own work. Meanwhile, they could also be taught about the importance of autonomy in their work through studying the history of engineering work. Much like artisans used craft tradition to impart a labor consciousness and sense of pride to their apprentices, engineering educators could use engineering history to show young engineers alternatives to current models and awaken them to labor solidarity.

While the challenges to incorporate the values of the artisan engineer into engineering work are many, the Jaipur Foot project is one engineering project that does it well. In a review paper on the Jaipur foot, for example, it has been pointed out that the development of the artifact (the Jaipur foot —a foot prosthetic for amputees) has taken local and cultural considerations into account (Meanley, 1995). This includes the availability of materials, the capability to manufacture locally, and the use of indigenous communities to devise solutions and ideas for the prosthetic foot. In many countries in tropical areas, barefoot walking or the use of open toed sandals is common, or footwear is removed when entering a home or place of worship. Those people needing prosthetic feet face unique difficulties in such environments. The Jaipur foot seeks to address this problem. Indeed, in response to requests by amputees wishing to wear and remove shoes, a Jaipur foot with a removable heel has been made to allow for the heel height of the shoe. The Jaipur foot also allows for squatting, absorbs torque sufficiently for cross-legged sitting, and facilitates walking on uneven ground. Some Jaipur foot prosthetics have even been designed to allow amputees to climb trees. This is an essential activity for picking fruit or collecting leaves or branches for animal fodder. In addition, the simple design of the foot is vital for rural communities where patients may live several days' walk from the prosthetics centre and cannot afford time away from the fields to attend a clinic for repairs. The Jaipur foot can also be created and repaired by local craftsmen. In this project, we can see that holistic production (craftsmen designing Jaipur feet), reciprocity (amputees able to dictate how the foot should be design and if its even needed by them), contextualization (allowing for bowing or climbing trees) are all valued. More engineering projects like this are needed.

Final Remarks

The arguments that we have brought forth in this chapter are our attempt to create an alternative to the traditional model of engineering, which has historically perpetuated killing of the environment and social relations. We believe that artisans promote nonkilling in their work and that engineers have much to learn from them. Therefore, we have tried to understand artisans and identify a set of ideal values in their relationship to work. It is our fundamental argument that a major shift in engineering culture that better reflects these artisan values would promote nonkilling and nonviolence. We invite others to create alternate models of what it means to be an engineer promoting nonkilling in their work

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Engineering Nonkilling Just Peace

An Opportunity for Responsible Action

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Introduction

Modern professional engineers change the world on a scale unprecedented in human history. Such engineering activities have the capability to profoundly affect the wellbeing of persons and the communities in which they live, both beneficially and deleteriously. Engineers are, therefore, presented with a major overall ethical challenge: can the great technical innovation of engineering be matched by a corresponding innovation in the expression and acceptance of ethical responsibility?

This challenge to engineers is arguably at its greatest regarding issues of peace and war. As we live in a world of limited resources, limited sympathy and limited rationality, competition leading to tension and conflict can arise. In such circumstances, a key responsibility of any society is to ensure the security of its citizens. The role of engineering in contributing to such security has usually been considered to be the development, manufacture and use of military equipment so as to ensure success if tensions result in violence. War is the normal business of engineering: almost a third of engineers in the US are employed in military related activities (Gansler, 2003) and the largest single employer of engineers in the UK is an arms producing company. The resources used are enormous, with world military expenditure in 2009 exceeding US$ 1531 billion (SIPRI, 2010).

To make a contribution to international security is a worthy goal for individual engineers and engineering enterprises. However, contributing by preparing for war is an inadequate response. In seeking to identify more effective alternatives, this article firstly summarises a philosophical approach to the overall nature of engineering. Secondly, recent analyses of the origins of conflict and their developing incorporation into government policy are outlined. Thirdly, some of the temptations of "advanced technology" are identified and a new description of advanced engineering is proposed. Fourthly, some legal considerations are indicated. Fifthly, some lessons that may be learned from the profession of medicine are considered. The final sections challenge engineers to identify ways of using their skills imaginatively and transformatively for the promotion of just peace. As will be discussed, just peace is characterised by relationships between individuals, and social groupings of all sizes, based on honesty, fairness, openness and goodwill. Such peace provides a basis for, and entails a commitment to, nonviolence and nonkilling.

The Overall Nature of Engineering

The overall nature of engineering may be clarified by considering it *as a practice*, "a coherent and complex form of socially established activity," of the type first proposed by MacIntyre (1981, 1985) (see Bowen, 2009). The UK Royal Academy of Engineering has provided a cogent and challenging description of what might be considered *the practice of engineering*:

> Professional engineers work to enhance the welfare, health and safety of all whilst paying due regard to the environment and the sustainability of resources. They have made personal and professional commitments to enhance the wellbeing of society through the exploitation of knowledge and the management of creative teams (RAE, 2007a).

Practices have a number of key features, including *internal goods*, *external goods* and *ends*. The *internal goods* of engineering are in particular those associated with technical excellence: the accurate and rigorous application of scientific knowledge combined with imagination, reason, judgement and experience. Such goods are best recognised by participation in the practice and characteristically benefit all who participate in the practice, and less directly all those affected by the practice. The *external goods* of engineering include considerable economic benefits to society, but particularly technological artefacts. Such goods are typically the possession of an individual or group. The *end* of engineering may be described as being to contribute to the flourishing of persons in communities through contribution to material wellbeing. The success of a practice is facilitated by human *virtues*, and those particularly necessary in the case of engineering are: accuracy and rigour; honesty and integrity; respect for life, law and the public good; and responsible leadership—listening and informing (RAE, 2007a; Bowen, 2009). Practices are sustained by *institutions*, which in the case of engineering include university departments, professional associations and commercial enterprises

Several features of the practice of engineering are especially relevant in the present context. Firstly, the practice is described as being concerned with the welfare, health and safety of *all*, an aspiration extending beyond the boundaries of nation states. This is a very demanding aspiration, which in many situations may be impossible to fulfill. However, it may be possible to identify certain activities, such as the design, manufacture and use of the many modern weapons of indiscriminate effect and huge devastation power that appear overwhelmingly to be outside the scope of such a practice. Secondly, a successful practice pays appropriate attention to all of its key constituent features. A cautionary note is required here. MacIntyre noted the dangers of too great a focus on external goods such as wealth, fame or power. In the case of engineering there is an additional and particular danger of focusing too greatly on the external goods of technological artefacts. Too great a prioritisation of the development of technically ingenious artefacts can lead to mistaking the external goods of the practice for the real end of the practice. For example, many engineers work in the military industries because of the opportunities to develop devices of great technical ingenuity. However, when engineering is considered as a practice, technological artefacts are only contingent products, external goods, in the pursuit of the flourishing of persons in communities. The prioritisation of technical ingenuity of a type designed to cause great human suffering and death is a very perverse approach to engineering.

Nevertheless, concern for the welfare, health and safety of all should naturally include consideration of actions that promote peace. Here a further feature of a practice is important: that its goods and ends should be *systematically extended*. The following sections will consider how recent analyses of the origins of conflict, government strategy and international initiatives suggest a re-prioritisation and extension of the role of engineering in the pursuit of peace.

The Origins of Conflict: Approaches to Peace and UK Government Strategy

Independent organisations such as the Oxford Research Group have provided perceptive analyses of current threats to peace and of the most effective responses (ORG, 2006). The Group identifies four factors as the likely root causes of possible future conflict and insecurity: (i) climate change—leading to loss of infrastructure, resource scarcity and mass displacement of peoples, causing civil unrest, intercommunal violence and international instability; (ii) competition over resources—including food, water and energy, especially involving unstable parts of the world; (iii) marginalisation of the majority world—increasing socioeconomic divisions and the political, economic and cultural marginalisation of the vast majority of the world's population; (iv) global militarisation—the increased use of military force as a security measure and the further spread of military technologies, including chemical, biological, radiological and nuclear weapons. The Group characterises the predominant current responses as a power projection control paradigm—an attempt to maintain the existing state of affairs through military means. It proposes that a more effective approach is a sustainable security paradigm—to cooperatively resolve the root causes of these threats using the most effective means available (ORG, 2006, 2010).

It will be noted that engineers can play a major role in resolving each of the four root causes identified. For example, development of renewable energy sources and transition to low carbon energy economies can reduce climate change; improved efficiency, better recycling and the introduction of innovative processes and materials can reduce resource competition; generation of wealth through the introduction of appropriate engineering processes in impoverished societies can diminish marginalisation; reducing or halting weapons development and reducing trade in arms can limit militarisation.

Despite the modest size of its population and its peaceful geographical location, the UK has the fourth highest military budget in the world in cash terms (after the USA, China and France), and the world's largest arms-producing company is also UK-based (SIPRI, 2010). UK security strategy therefore has global significance,[1] and it was first clarified in a single document by a recent government (CO, 2008). That publication made clear that "The broad scope of this strategy also reflects our commitment to focus on the underlying drivers of security and insecurity, rather than just immediate threats and risks". It further recognised that climate change, competition for energy and water stress are "the biggest potential drivers of the breakdown of the rules-based international system and the re-emergence of major inter-state conflict, as well as increasing regional tensions and instability".

The consonance of these aspects of the strategy document with the Oxford Research Group's analysis is striking, and the challenge to engineers is again clear. The same recent UK government also created an initiative specifically "to help manage conflict and stop it spilling over into violence...Preventing conflict is better and more cost effective than resolving it" (FCO, 2003). However, though this strategy and initiative were very welcome, there was tentativeness about their implementation. Thus, the total UK budget for conflict prevention and peacekeeping has been only about 1-2% of that for direct military expenditure, and of the same order as subsidies to arms exporters (El-

[1] This article will hence focus mainly on the United Kingdom, though similar developments are taking place in other countries.

worthy, 2004; Kinnock, 2010). Furthermore, much of this limited budget has been used to place military personnel in peacekeeping roles rather than to use civilian means for the amelioration of the root causes of conflict. Such budgets are ethical documents: they show where priorities really lie.

Thus, in the years before 2010 the UK government at that time was showing signs of moving very tentatively in the direction of sustainable security. However, two factors arose in May 2010: (i) an election resulting in a coalition government with a broader view of security, and (ii) the financial necessity of reducing overall government spending so as to ensure a balanced national budget. An early initiative of the new government was the creation for the first time of a National Security Council. The broad remit of this Council is indicated by its high level membership: Prime Minister, Deputy Prime Minister, Secretary of State for Foreign and Commonwealth Affairs, Chancellor of the Exchequer, Secretary of State for International Development, Home Secretary, Secretary of State for Defence and the Secretary of State for Energy and Climate Change. Then, in October 2010 the government published two key documents: *The National Security Strategy* and *The Strategic Defence and Security Review* (HM Government, 2010a and b).

The *National Security Strategy* sets out two core objectives: (i) ensuring a secure and resilient UK, and (ii) contributing to shaping a stable world. It describes a commitment to a "whole government" approach based on "a concept of security that goes beyond military effects": "We will use all the instruments of national power to prevent conflict and avert threats beyond our shores: our Embassies and High Commissions worldwide, our international development programme, our intelligence services, our defence diplomacy and our cultural assets". The document reports the National Security Council's judgement of the four highest priority risks over the next five years: (i) international terrorism, (ii) cyber attacks, (iii) international military crises, and (iv) major accidents and natural hazards. Eleven less likely risks are also identified, categorised in two further tiers of priority. The document gives high priority to tackling the root causes of instability, identifying such causes as competition for resources, marginalisation, environmental factors and climate change. The *Strategy* suggests a strong commitment to change: "we have inherited a defence and security structure that is woefully unsuitable for the world we live in today. We are determined to learn from those mistakes, and make the changes needed".

The *Strategic Defence and Security Review* provides more detail on the implementation of the *Strategy*. It is worth listing the six parts of the *Review* as they give a sense of its emphases: (i) National security tasks and planning guidelines, (ii) Defence, (iii) The [nuclear] deterrent, (iv) Wider security, (v) Alliances and partnerships, and (vi) Structural reform and implementation. Overall, it seems that although wider security is given significant attention, the emphasis and budget allocations still prioritise military solutions. Thus, although only one of the four highest priority risks (international military crises, and this is expressed vaguely)[2] could be clearly addressed by the sophisticated weaponry that engineers have developed in recent years, the *Review* nevertheless prioritises expenditure on exactly that sort of military equipment: aircraft carriers, "hunter-killer" submarines, naval destroyers, combat jets and nuclear weapons. These represent a continued commitment to an outdated "Cold War mindset" which the Strategy elsewhere criticises: it recognises that "we face no major state threat at present and no existential threat to our security, freedom or prosperity". The only specified major change in expenditure that could benefit the *Strategy's* core objective of contributing to shaping a stable world is a proposed increase of Official Development Assistance to 0.7% of Gross National Income over the next three years, with 30% of this being used "to support fragile and conflict-affected states and tackle drivers of instability". This remains a small amount of finance compared to the military budget and doubts have been expressed as to whether even this modest reprioritisation will be met. In short, the *Review* does not adequately implement the analysis of the *Strategy*.

Neither *The National Security Strategy* nor the *The Strategic Defence and Security Review*, which together run to one hundred and thirteen pages, uses the word "engineering" even once. Given the subject matter, this could in a curious way be considered a remarkable achievement, though not one worthy of commendation. However, science and technology are mentioned, including an important role for the National Security Council to "provide focus and overall strategic direction to the science and technology capability contributing to national security, so that decisions by individual departments and agencies take account of the needs of Government as a whole and make best use of available resources". These factors

[2] The use of conventional military force to address the threat of terrorism is regarded by key experts as counter-productive. Thus, the Director General of the UK security service MI5 between 2002 and 2007 has advised that "the invasions of Iraq and Afghanistan radicalised parts of a generation of Muslims who saw the military actions as an "attack on Islam"... Arguably, we gave Osama bin Ladin his Iraqi jihad" (Manningham-Buller, 2010). The Chief of the UK Defence Staff regards military victory against al-Qa'ida and the Taliban as not possible (Richards, 2010).

provide a challenge to engineers to make known to the Council the ways in which engineering can make unique contributions to fulfiling the core security objectives through civilian means. Such knowledge could benefit international peace, national security and commercial engineering enterprises.

Advanced Technology and Advanced Engineering

The *National Security Strategy* has specified in an authoritative way that the UK faces no risks that require much of the sophisticated weaponry that so many engineers spend their professional lives developing. Nevertheless, the *Strategic Defence and Security Review* retains a strong commitment to such weaponry, perhaps because of a lack of consistent political commitment and certainly reflecting the strong political influence of arms companies and the military hierarchy in the UK. However, engineers are often attracted to work for arms companies by another factor: the opportunities they offer for working on the development of highly sophisticated technology.

Such development of sophisticated weapons technology takes place to a large degree in a context of "ethical bracketing". This begins with the manipulation of language even in descriptions of core business, so a commonly chosen designation of arms producing companies is "defence and aerospace", where even the military connotations of defence are diluted by the addition of aerospace. The work of individual engineers in such companies may be described in similarly euphemistic terms. Further, there will be a strategy of minimising the individual's appreciation of the overall purpose of his or her work, so that its real purpose is not clearly apparent. Ignorance of the final purpose of one's work activities may also be voluntary, resulting from an attitude of failing to take the trouble to find out. However, such ignorance can nevertheless be culpable: awareness of the overall consequences of one's work is surely a key requirement for any professional.[3]

The United Nations Foundation (2008) estimates that ninety percent of those killed, wounded or displaced in violent conflict are (civilian) women and children. An argument is sometimes used by arms producers along the lines that more technically-sophisticated weaponry can reduce civilian casualties. The specific design of many modern weapons to cause indiscriminate and disproportionate injury and death, in contravention of international treaties and conventions, suggests that such an argument cannot be entirely true. Indeed, a detailed study of casualties in Iraq in the period 2003-2008

[3] See Foot (2001: 70-71) for a description of culpable ignorance using arms dealing.

shows that sophisticated weaponry resulted in a greater proportion of indiscriminate civilian deaths of women and children than more primitive techniques (Hicks et. al., 2009). Experts advise that the patterns found in Iraq are likely to be replicated wherever similar weapons are used.

One of the key promoters of ethical action is proximity. Indeed, Levinas (1961/1969) has defined an ethical act as "a response to the being who in a face speaks to the subject and tolerates only a personal response". Correspondingly, it is known that even highly trained soldiers are averse to killing at close range. However, sophisticated weapons technology that allows killing at great distances is increasingly being developed and used. For example, unmanned aerial vehicles, also termed drones, are widely used in Afghanistan whilst being controlled from Nevada, USA. Some are used for surveillance, but others are equipped with bombs and missiles. They seem to cause civilian casualties to a similar extent to other "advanced" weapons. Great concern has been expressed about their use. Thus, a report to the United Nations General Assembly Human Rights Council (UN, 2010) has described such weapons, which are operated through computer screens, as giving rise to a risk of a "Playstation" mentality to killing. Again, one of the most senior UK judges has compared drones to internationally forbidden weapons such as land mines and cluster bombs, "so cruel as to be beyond the pale of human tolerance" (Bingham, 2010). A further concern is the use of drones for targeted killings ("state-sanctioned assassinations") outside of war zones. For example, there were more than twenty such attacks by US drones in Pakistan in September 2010, and they have been used in other states outside war zones, such as Yemen. Such use is authoritatively regarded as being in most circumstances illegal under international law (UN, 2010).

Commercial engineering enterprises usually take great care to fully assess and make known the effect of their activities on persons, communities, the environment and the economy. However, there are a number of such crucial assessments about the engineered products of arms companies that have not been carried out but which need attention at all levels, from government to the individual engineer seeking employment. Thus, framing some such questions from an overall UK perspective: (i) How many civilians are killed or injured annually by UK engineered armaments? (ii) How many civilians die or suffer illness from preventable causes annually in developing countries as expenditure has been made on UK engineered armaments rather than the development of essential infrastructure such as clean water and sanitation? (iii) How much is the quality of life in developing countries otherwise diminished due to such arms-expenditure (lack of schools, roads, telecommunications)? (iv) What is the loss to wellbeing in the UK and to the competitiveness of UK industry due to many of the most able engineers working on military projects rather than civilian projects?

These questions return the discussion to the basic issue of the overall nature of engineering. Sophisticated weapons systems may well represent "*advanced technology*". However, technological artefacts are only part of the practice of engineering, examples of external goods. Engineers need also to consider the other key constituent features of their practice, including internal goods, ends, virtues and the systematic extension of the practice. *Advanced engineering* will, in particular, seek to balance these constituent features in a way that seeks *to enhance the welfare, health and safety of all*. The crucially important point is: advanced engineering is not synonymous with advanced technology.

Some Legal Considerations

The relationship between ethics and law is complex, but the development of law has certainly been profoundly influenced by ethical priorities (Hart, 1961/1994). Respect for law has been identified as a key element in the ethical practice of engineering: "Professional Engineers should give due weight to all relevant law…ensure that all work is lawful…act honourably, responsibly and lawfully" (RAE, 2007a). It is therefore pertinent to give attention to some legal issues that may affect an ethical approach to war and peace.

Recognition of the undesirability of war has led to the formulation of a number of significant international conventions and treaties. Two which are especially relevant in the present context are: the *Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (Protocol 1), 8 June 1977* and the *Treaty on the Non-proliferation of Nuclear Weapons (NPT)* which was first signed on 1 July 1968 and entered into force on 5 March 1970.[4] An indication of their scope and importance may be given by drawing attention to a salient point in each.

An important aspect of *Protocol 1* is the protection of the civilian population in the event of hostilities. The basic rule is set out in Article 48:

[4] The full texts of relevant international conventions and treaties are available on the websites of international organisations such as the International Committee of the Red Cross, the International Atomic Energy Agency and the United Nations.

> In order to ensure respect for and protection of the civilian population and civilian objects, the Parties to the conflict shall at all times distinguish between the civilian population and combatants and between civilian objects and military objectives and accordingly shall direct their operations only against military objectives.

However, as has been noted in the previous section, ninety percent of those killed, wounded or displaced in violent conflict are civilian women and children. Indeed, many modern weapons have enormous indiscriminate destructive power, and the evidence shows that more "sophisticated" weapons can be in practice the least discriminate. Thus, *Protocol I* should give engineers involved in weapons production serious cause for reflection on the legality of the use of the technological artefacts they are developing.

The *NPT* is concerned in particular with nuclear weapons: "Considering the devastation that would be visited upon all mankind by a nuclear war and the consequent need to make every effort to avert the danger of such a war and to take measures to safeguard the security of peoples". The *NPT* consists of eleven articles, and it is here relevant to consider particularly Article VI which relates to complete disarmament:

> Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a Treaty on general and complete disarmament under strict and effective international control.

This article has so far had regrettably little effect, and it notably omits any timescale. However, it should also give engineers involved in weapons development serious cause for reflection on the legality of the use of the technological artefacts they are developing. It also implies a challenge to find better ways for the prevention and resolution of conflict.

A further issue at the boundary between law and ethics requiring consideration is the status of individual engineers involved in military work. Military personnel may be considered to have been authorised to use lethal force (HM Government, 2010b), subject to observance of international law, and therefore are in normal circumstances immune from prosecution for such actions. However, most engineers involved in the development, manufacture and use of military equipment are civilians and are hence subject to different legal frameworks. For example, civilian engineers involved in the use of remotely controlled drones for targeted killing do not have immunity from prosecution under domestic law for their conduct and could be prosecuted for murder (UN, 2010).

In certain circumstances, legal liability may also arise for those considered accessories to specified types of violent military action. Thus, the International Criminal Court (ICC) was established in 2002 as a permanent tribunal to prosecute *individuals* for four categories of actions: (i) genocide, (ii) crimes against humanity, (iii) war crimes and (iv) crimes of aggression. The Court was established by the *Rome Statute*, which also defines its responsibilities. Article 25 of this statute includes in its description of individual criminal responsibility:

> In accordance with this Statute, a person shall be criminally responsible and liable for punishment for a crime within the jurisdiction of the Court if that person: (a) Commits such a crime, whether as an individual, jointly with another or through another person, regardless of whether that other person is criminally responsible; (b) Orders, solicits or induces the commission of such a crime which in fact occurs or is attempted; (c) For the purpose of facilitating the commission of such a crime, aids, abets or otherwise assists in its commission or its attempted commission, including providing the means for its commission.

Article 27 specifies that such responsibility is irrespective of official capacity: "The Statute shall apply equally to all persons without any distinction based on official capacity". Thus, an engineer knowingly involved in the development and manufacture of weapons used for genocide, crimes against humanity, war crimes and crimes of aggression could be liable to prosecution for assisting in the provision of the means for commissioning such crimes.

Learning From Other Professions: A Comparison With Medicine

Engineering has been described as a profession that seeks "to enhance the welfare, health and safety of all". Such a description may be understood as referring to both human collectivity and the human quality in each person. On the way to proposing a reprioritisation and extension of the role of engineering in the promotion of peace it can be helpful to consider the attitude to war and peace in another profession which seeks to promote health and welfare: medicine.

Although it may at first appear that medicine is concerned with individual persons and that engineering is concerned with communities, both are in fact better described as being concerned with persons in communities, though with differing emphases. This overlap may be illustrated by considering a recent poll conducted by the *British Medical Journal*, which asked readers to vote for the most important advance in medicine since 1840. The most supported advance was water supply systems and sewage disposal (sanitation) which is strictly speaking an *engineering* advance rather than a *medical* advance (BMA, 2007a). Further, and more generally, the first levels at which new medical treatments are quantified are statistical significance and clinical significance, which are both based on populations. Only subsequently is the appropriateness of a treatment for an individual patient assessed by a doctor. Correspondingly, though engineers often seek to benefit whole communities they also need to seek to ensure that no individual person is unfairly disadvantaged by their work.

Medicine is a profession that works on the basis of an unequivocal presumption in favour of preserving life. Indeed, it devotes much care and effort to considering the best clinical practice even under the very adverse circumstances which may arise towards the unavoidable end of an individual's life (GMC, 2010). Thus, it may be possible to gain some insight into new approaches for engineering nonkilling, and hence life preservation, by consideration of a specific issue concerning both the medical and engineering professions: the considerable work being undertaken by governments, industries and universities on military applications of new biological knowledge. There appears to be particular interest in substances with neurological properties, causing unconsciousness, memory loss, panic attacks or influencing emotions. Acquisition of genome and proteome information, or use of variability in cell surface chemistry, may allow the design of ethnically targetable pharmaceutical weapons.

One of the ways in which acceptance of these approaches may be induced is through the use of misleading or ambiguous terminology. Hence, "drugs as weapons" is a term invoking the benefits of medicines, in much the same way that a bombing raid may be described as a "surgical strike" in an attempt to allude to a beneficial medical procedure. These approaches are also frequently categorised as one of a group of "nonlethal weapons" (others include electromagnetic and acoustic devices), with the suggestion that the alternative is the use of lethal force. However, as will be shown, this can be a very misleading designation.

One way in which the skills of engineers could be exploited in the development of such weapons is in the scale-up of the production, purification and encapsulation of the active ingredients. These procedures would be similar to those already used for beneficial purposes in the pharmaceutical and biotechnological industries. However, engineering knowledge is also required for their deployment. For example, studies have already been made of the design of special equipment for their delivery as aerosols. Further, mathematical modelling skills will be necessary to predict the way in which such aerosols would be delivered to targets taking into account the nature of the physical environment and atmospheric dispersion conditions.

The British Medical Association (BMA), which represents doctors in the UK, has provided very explicit overall guidance on the involvement of doctors in weapons development:

> While doctors may have a legitimate role in reviewing the defensive capability of weapons, the BMA considers that doctors should not knowingly use their skills and knowledge for weapons' development. It objects to doctors' participation in weapons' development for the same reasons that it opposes doctors' involvement in the design and manufacture of torture weapons and more effective methods of execution: through their participation doctors are lending weapons a legitimacy and acceptability that they do not warrant. Doctors may consider that they are, in fact, reducing human misery through their involvement, but in reality the proliferation of weapons shows this to be untrue. (BMA, 2001)

However, such is the concern about the use of drugs as weapons that the BMA has also published a specific detailed assessment of the topic (BMA, 2007b). The overall conclusion is that "the BMA is fundamentally opposed to the use of any pharmaceutical agent as a weapon". Three key reasons are: (i) the need to uphold existing international law unequivocally (BTWC, CWC)[5], (ii) the danger of the spread of such technology to other state and non-state actors, and (iii) that such use would be the top of a "slippery slope" leading to the general militarisation of biology. Two further reasons leading to this overall conclusion are of particular importance in the present context. The first may be described as technical: the multiple, and probably insurmountable, difficulties that will prevent the use of drugs as weapons without causing innocent deaths and disability. This may be quantified in terms of the narrow range separating the response curves for effective doses and lethal doses of all known drugs combined with the difficulty of dispersing a drug (probably in the atmosphere) in such a way that it rapidly achieves the required influence. The second is ethical and crucial:

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[5] BTWC (Biological and Toxin Weapons Convention), *Convention on the prohibition of the development, production and stockpiling of bacteriological (biological) and toxin weapons and on their destruction*, 1972; CWC (Chemical Weapons Convention), *Convention on the prohibition of the development, production, stockpiling and use of chemical weapons and on their destruction*, 1993.

> ...the BMA does not believe it is part of a doctors' role to develop weapons to harm people, even in order to fight terrorism, since that is contrary to the ethos of medical training...In other words, the duty to avoid harm rises above, for instance, a duty to contribute to national security. (BMA, 2007b)

This authoritative analysis by the BMA should also give cause for concern to any engineer approached with a proposal for work in this area. The arguments for unequivocally upholding international law are very strong. The technical reasons indicating the great difficulties in producing such a weapon in a "nonlethal" form are further great cause for concern. Most importantly, if engineering is genuinely also a profession seeking to enhance the "welfare, health and safety of *all*", then engineers should give serious consideration to the ethical reasons presented by the BMA.

Engineering and medicine, or their precursors, have made important contributions to human flourishing since earliest times. More recently, and especially during the 20th century, their ethical paths have diverged and though engineering has continued to make vital contributions to human wellbeing it has been used increasingly for military purposes. However, medicine as a profession retains its overriding commitment to the preservation of life, as shown by the BMA's analysis of drugs as weapons. A recent incident in Norway further illustrates the strength of such commitment. The involvement of the Norwegian military in Afghanistan led to a government proposal to double the number of military doctors, with the intention of basing four in a department of acute medicine at the University of Tromsø. However, the head of this department, Mads Gilbert, an internationally-leading specialist with extensive humanitarian experience in conflict zones, objected to these appointments on the grounds that they would compromise the hospital's role as a civilian hospital, and additionally that they would compromise the independence of Norwegian humanitarian work overseas. Eventually, Gilbert resigned as head of department, but the new military doctor appointments remain unfilled three years later (Grundseth and Akerhaug, 2010).

Engineering for *Nonkilling Just Peace*

Engineers have at present an unfortunately high level of involvement in the development, manufacture and use of weapons of enormous and indiscriminate devastation power. The victims of the use of such weapons are overwhelmingly civilians. However, none of the present or likely future threats to the security of the UK can be best met by the use of such weapons. Furthermore, analysis by leading NGOs and UK government strategy clearly prioritise the long-term prevention of conflict. However, the proposed practical implementation of this strategy is inadequate. In contradiction of its own strategy, the UK government continues to fund the development and commissioning of large-scale, complex, engineered weapons systems of a Cold War type.

The strategy of long-term conflict prevention can benefit greatly from the appropriate and peaceful application of engineering. However, official documents show that this capacity of engineering is not recognised by government. Hence, if engineers are to fulfill their ethical task of responsible leadership (RAE, 2007a), it is incumbent upon them to make such potential applications known. Such an initiative would be fully consonant with a profession committed to "enhancing the welfare, health and safety of all" within a practice which values internal goods, external goods, an end of contributing to the flourishing of persons in communities, and which seeks the systematic extension of these factors. Such a commitment to nonviolence and nonkilling would also be consonant with the approach of the medical profession (which more generally also prioritises health through prevention where possible). Furthermore, the current trend for change in government analysis of defence and security make the present a very opportune time for making such a change in the direction of engineering.

The absence of conflict is a necessary but not sufficient condition for peace. Peace is additionally characterised by relationships between individuals, and social groupings of all sizes, based on honesty, fairness, openness and goodwill. Hence, if engineering is to contribute fully to the prevention and resolution of conflict, and to the establishment of genuine peace, it needs to align its activities with those of other like-minded individuals and institutions in a way that is sensitive to cultural, societal and political factors. A promising way forward is to consider how engineering can contribute to nonkilling and a *just peace*.[6] The nature of this approach may be illustrated by reference to a recent multi-author work, *Just Peacemaking* (Stassen, 2008), here additionally summarising the potential contribution of engineering to six of the main themes identified in that work:

Advance, democracy, human rights and interdependence. Many of the world's violent conflicts occur in and between countries which are undemocratic, have poor human rights records and which are in differing ways isolated from the international community. Engineering can promote de-

[6] This is to be contrasted with the emphasis in the philosophical literature on "just war", which focuses on when military action is right or wrong. Such a traditional focus moves even the start of a discussion to military rather than peaceful considerations.

mocracy, human rights and interdependence by providing appropriate technologies for the effective collection and distribution of information. Engineers should also be aware of the dangers of developing and supplying technology that can be used to suppress democracy and human rights. Simple technologies can promote societal equality: for example, in poor and arid countries, drilling convenient wells frees women from the onerous task of collecting water from remote sources hence promoting gender equality.

Foster just and sustainable economic development. In less-developed parts of the world this can be especially stimulated by provision of basic infrastructure such as clean water and sanitation (Hutton and Haller, 2004). In such contexts, a particularly fruitful approach is that of Engineers Against Poverty, which provides advice to major companies on innovative ways of addressing social issues (Duckett, 2007). In developed countries it is important that major engineering projects seek to avoid the exclusion of vulnerable persons or sections of society. In all societies, discontent can arise through knowledge of the possible as contrasted with the actual. A major world-wide challenge is the provision of sustainable energy sources at reasonable cost.

Work with the emerging cooperative forces in the international system. During the twentieth century, individuals could mostly be considered as citizens of particular nation states. However, with the growth in the many types of communication which engineering provides, individuals may increasingly be regarded as civilians on a global scale, able to interact significantly with others without political, economic, cultural or social boundaries (Frost, 2009). Expanding the role of such a borderless, global, civil society can promote understanding in a way that establishes peace. However, such interaction outside the structure of nation states may also promote violence, whether through terrorism or the actions of private military companies (mercenaries). Engineering needs to pay attention to how best to promote only the peaceful aspects of such interactions.

Strengthen the United Nations and other international cooperative efforts. The United Nations makes a major contribution to sustainable peace through its many declarations and actions, such as the Universal Declaration of Human Rights, the Millennium Development Goals, its peace-keeping initiatives and its role in coordinating humanitarian relief. A key initiative in the present context is the promotion of a Culture of Peace (UN, 1999, 2006). The UN recognises they key role that may be played in this initiative by "parents, teachers, politicians, journalists, religious bodies and groups, intellectuals, those engaged in scientific, philosophical and creative and artistic activities, health and humanitarian workers, social workers, managers at various levels as well as non-governmental organisations" (UN, 1999). It is notable that engineers are not mentioned in this list, an omission that should stimulate engineers and engineering institutions to make their potential contributions better known to such international organisations. The recent initiatives of the World Federation of Engineering Organisations in this direction are welcome and worthy of emulation.

Reduce offensive weapons and weapons trade. There is a huge oversupply of weapons of all types in the world. The governments of some countries, such as the UK and USA, spend substantial resources on the marketing of weapons, in essence subsidising the commercial arms companies. Even countries with reputations as promoters of peace, such as Norway, are significant arms exporters. However, weapons of almost all types could not be designed, manufactured or deployed without the extensive involvement of engineers. A major theme of this article is that this is a very perverse use of engineering skills. Engineers need to think much more carefully about how they use their skills, taking into account all of the essential facets of the practice of engineering. Indeed, the adaptable skills of engineers give them a key role in practically promoting the current tentative moves toward non-military, sustainable security and peace.

Encourage grassroots peacemaking groups. Scholars and activists developing approaches to just peace recognise the need not just for individual peacemakers but also for communities of peacemakers. They envisage these as arising in the various types of institutions in our societies. Engineering may again play a key role. The practice of engineering is supported by various types of institutions, such as university departments, professional associations and commercial enterprises. The challenge is to create a culture of peace within these institutions. For example, engineering education needs to teach the role of engineering in enhancing the welfare, health and safety of all—and of the multi-faceted nature of the practice of engineering with its requirement for considering, in a balanced way, internal goods, external goods, virtues, ends and systematic extension. Professional associations need particularly to inform governments and international bodies of the possible role of engineering in benefiting the development of societies in peaceful ways. The present ignorance of the potential of engineering among key decision-makers is a serious cause for concern. Commercial engineering enterprises need to develop their businesses in ways that truly seek to benefit all persons and the communities in which they live. This may involve changes in business directions. Such changes may become essential for arms companies: if government strategy is realised practically there will be a substantial decrease in the need for "advanced" weapons. However, the strong engineering skill-base of such companies will enable them to play a key role in the development of engineering for sustainable and just peace.

These six themes were identified as a result of scholarly collaboration. The United Nations has itself identified eight action areas for developing a Culture of Peace (UN, 2006): foster a culture of peace through education; promote sustainable economic and social development; promote respect for human rights; ensure equality between men and women; foster democratic participation; advance understanding, tolerance and solidarity; support participatory communication and the free flow of information and knowledge; and promote international peace and security. These show considerable agreement with the scholarly themes, and engineering again has the potential to make a significant contribution to each action area (Bowen, 2009). At a more technical level, the UK Royal Academy of Engineering has presented a collection of ideas to illustrate the complexity of the expected greatest challenges of the next 100 years for which engineering-led solutions are needed (RAE, 2007b): supply of affordable and sustainable energy; smart use of energy; global infrastructure; climate change; understanding the brain; human level computing; inside-out surgery; large-scale vaccine production (to prevent pandemics); potable water; managing knowledge; and transition to cyberspace market. Though not specifically developed in the context of peace and security, these again show considerable overlap with both the scholarly and UN priorities. The challenge is for engineers across the breadth of the practice to propose specific technical solutions to these needs.

Concluding Aspiration

During the twentieth and early twenty-first centuries, generations of the most able engineers worked on the development, manufacture and use of weapons. Now, in response to careful analysis of the nature of possible threats, and through financial necessity, governments are realising that there are better ways to ensure sustainable security and peace. Civilian engineering has enormous potential for contributing to this goal. Fulfillment of this potential has two important preconditions. Firstly, we need to promote an ethos within engineering that genuinely seeks the wellbeing of all and is fundamentally committed to sustainable peace, nonviolence and nonkilling. This will need the incorporation of increased degrees of compassion and generosity in the carrying out of our tasks. Secondly, we need to take greater responsibility for informing politicians and other decision makers about the peaceful capabilities of engineering. Their documented current lack of such awareness is a cause for serious concern. Fulfillment of both of these preconditions can benefit from creative reflection on the key features of engineering as a practice. Engineers may then be able to make imaginative and transformative contributions to creating and maintaining *just peace* in a killing-free world.

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Mathematics for Building a Nonkilling Ethos

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Mathematics in essence deals with abstract symbols and concepts. But being a human activity its constructive as well as destructive applications have been witnessed. Of late, mathematics is found providing or guiding instruments used for killing on a mass scale, particularly in warfare. It is high time we rather pledge to employ only its positive and society binding features to sustain civilization. Mathematical techniques for conflict resolution such as compromise programming, for example, can help to a certain extent in this direction.

Even today killing is frequently resorted to get rid of individuals or groups that may have even marginally differing perspectives of life. Dissimilarities in religion, ideology and culture are often treated as evil and elimination of their adherents is presumed to be a sacred duty in many instances. It is overlooked that such diversity has been and is necessary for human survival and progress. The analogy from geometry namely, the development of non-Euclidean geometries vis-à-vis Euclidean geometry illustrates this point succinctly. There are several other mathematical concepts and methods to assist checking the rise of killing situations.

We need to drive home the message that we should nurture the immense power of mathematics for the furtherance of mankind. Suitable changes in teaching, regular application of mathematical methods to manage the conflicts, and use of information and communication technology to project the positive role of mathematics should be utilized for this purpose.

Introduction

Though mathematics in its rudimentary form started with counting and simple arithmetic, first to facilitate the royal administrative operations like land measure and tax collection and then for common daily transactions, mathematics for the sake of mathematics in large part has been the guiding principle for its development. Only with the Renaissance has its application been systematically undertaken in various fields, and that in turn led to further developments in mathematics. It is amazing to note that in the year 1868 mathematics was divided into 12 branches with 38 sub-branches (Davis and Hersh, 1981), whereas in the year 2000 the number of branches has grown to 63 with more than 4,500 sub-branches. That gives an idea of the rapid expansion and diversification in the field of mathematics. Interestingly, 95 percent of the existing knowledge of mathematics has developed only since 1900 CE.

Mathematics is primarily a human activity and, therefore, its use for both good and harmful purposes cannot be avoided. On the positive side establishment of computer-based global banking systems, development of metropolitan city-wide water, transport and other utility networks, and launching of satellites for exploring the outer universe have been possible due largely to the assistance of mathematics. Gambling, on the other hand, which irrespective of its form essentially depends on mathematics, has been the cause of ruin of countless individuals and even empires. In other words mathematics on its own does not dictate the kind of application. Some of its innocuous products, however, are found to be double-edged. That means their beneficial uses in normal times can be found aiding killing forces in war operations. For instance the logarithmic tables that helped Kepler to establish his famous three laws of planetary motion, also proved useful to direct the guns and cannons for increasing firing accuracy in numerous battlefields. It is no wonder that application of mathematical war technology for the purpose of killing on different scales is a fact of life. Sufficient historic evidence is available—particularly from the time of Archimedes (287-212 BCE), to the Second World War, to the latest Iraq and Afghanistan war—to show that mathematics, directly or indirectly, has enhanced our capacity to kill and wipe out the habitat on an unprecedented scale.

The above argument that mathematics, like fire, is basically neutral and pure in its construct and it is man who molds it to design lethal weapons and other means of destruction or counterattack is true, but only partially. One reason for this skew is that the power of mathematics was recognised early by military establishments, who ensured the adequate flow of funds and other resources for its development to support warfare objectives. Induction of select young mathematicians by the military intelligence agency of Poland in the early 1930s to break the famous "Enigma" code used for secret communication by German forces is a classic example in this regard (Rakus-Andersson, 2003). Their work was later extended by another mathematician, namely Alan Turing who was commissioned by the Defence Ministry of Britain. It is no surprise that next to teaching (formal and private), the department of defence of a nation and its allied agencies all over the world employ the largest number of mathematicians. Their tasks vary from increasing weapon firing efficiency to designing proficient antisubmarine operations in a given section of the ocean. The glamour associated with such work receives more celebrity attention because it leaves a deep impression on the human mind. And, of course, such acts are often glorified by the media, sometimes disproportionately.

It is time to bring the equally important progress and development facilitating power of mathematics to greater prominence. Interplay between abstract constructions of pure mathematics and practical problem-solving capacity of applied mathematics in this respect is to be portrayed. If projected imaginatively, the qualities of mathematics that help deter killing and offer relatively stable solutions for resolving complex conflict by following an all-inclusive approach would be appreciated by people at large. Such promotion is to be done through means such as case study based writing, teaching, public lectures, and demonstration of welfare furthering capabilities of mathematics. Modern communication means of electronic media and the Internet can certainly contribute significantly to these efforts.

The aim of this paper is to show how different concepts from mathematics can help to develop nonkilling attitudes and direct attention to its humanity binding and prospering potential. Support of information and communication technology for this purpose is also highlighted.

Genesis of Killing

Greed for material possession, insecurity due to external and internal threats, and ideological differences due to such factors as religion, race, class, language and culture are found to be the leading causes for killing at individual, group and even international levels. Further, human psychology suffers from two sicknesses, namely, promoting vendettas across generations and the tendency to label people as groups responsible for the trouble rather than particular individuals. It is no wonder that more often than not, innocent persons suffer because they simply may fall under such condemned group labels by conditions beyond their control.

A substantial number of killing cases is also found arising out of the following widely-held myopic or fractured adherences; among many:

a) ours is the best worldview (e.g., religion or culture) and, therefore, those holding other views need to be eliminated as they have no right to exist, and
b) fair distribution of resources is not possible, and therefore, to resort to killing is justified to grab the pie.

Rigid attitudes as reflected by a) above is one of the root causes of conflict which escalates to bloodbath at the slightest provocation. This attitude is counterproductive and is seldom realized and projected. In this context the development from geometry is useful to show that an alternative worldview is perfectly justifiable and co-existence of various systems in fact supplements each other for sustenance. We shall elaborate on this idea in the third section of the paper.

An enormous amount of literature in fields such as mathematical programming, economics, and management offers methods to address the issue of resource distribution raised by b) above. These methods are by and large found effective at a macro level. But at a local level, the technique of compromise programming can be gainfully employed to suggest solutions that can contain the conflicts, at least for some period, during which further options can be developed to settle the issue. That will be the subject matter of our fourth section.

Application of mathematics can amply guide the negotiation process leading to avoidance of human killing. In other words to promote nonkilling conditions, developments from mathematics can certainly help. This also includes cases of killing that occur from accidents due to design failure (e.g., faulty vehicles, poor road geometrics, and signal malfunctioning) and manmade disasters (e.g., Bhopal gas leak and meltdown of Chernobyl nuclear reactor). Considerable mathematics-based technological knowledge is available to minimize such tragic incidents. It would be a great folly if we do not understand and exploit the power of this distinct asset of mathematics, which no other living creature on the earth is possessing.

Non-Euclidean Geometries

Euclid (325-262 BCE) customarily is given the credit of developing what is now called plane geometry. He systematically drew upon the logical argument framework put forth and fortified successively by Socrates (477-399 BCE), Plato (428-348 BCE), and Aristotle (384-322 BCE) to give a solid foundation to his work. In particular, besides giving 23 definitions (such as that of point and straight line) and five common notions (such as things equal to the same thing are also equal to each other and the whole is greater than the parts), he assumed the following five axioms to construct the entire edifice of geometry in the form of 465 propositions (theorems) proved in his celebrated 13-part work called *Elements* (specifically, in the papyrus rolls called *Books* I-IV & VI) (Euclid, 1956):

1. A straight line can be drawn from any point to any point.
2. A finite straight line can be extended continuously in a straight line.
3. A circle can be formed with any centre and distance (radius).
4. All right angles are equal to one another.
5. If a straight line falling on two straight lines makes the sum of the interior angles on the same side less than two right angles, then the two straight lines, if extended indefinitely, meet on that side on which the angle sum is less than the two right angles.

Or, equivalently formulated by Playfair as "Through a point not on line, there is exactly one line parallel to the given line."

There have been doubts about the self-truth of the above stated fifth axiom, but still for about two thousand years Euclid's geometry was assumed to be perfect, unique and absolutely valid. However, N. Lobachevsky in Russia (1829) and J. Bolayi (1832) in Hungary proved independently that if "one line" in the above Playfair's formulation of the fifth axiom of Euclid is replaced by "more than one line" the resulting system contains no contradictions. B. Riemann (1854) found the same if "no parallel line" is substituted in that place. The basic difference is that geometry developed by Lobachevsky and Bolayi holds well on the hyperbolic surface while that developed by Riemann works on the spherical surface. It is thus implied that Euclid's geometry is valid only for the plane surface and it is one out of many possible geometries that can be constructed. All such other forms are now called non-Euclidean geometries (Gray, 2007; Wolfe, 1945).

Interestingly, Euclidean geometry is still found useful for most daily activities, whereas Riemannian geometry is helpful to study distant galaxies in astronomy, and Lobachevskian and Bolayi's geometry is valuable in sub-atomic physics studies. The study of geometry has expanded ever since this breakthrough and continues to do so fascinatingly (Hartshorne, 2000). All these geometries coexist and none is claimed to be superior to others. Usefulness of each form of geometry depends on the context of application.

There is no doubt that ideas of Lobachevsky, Bolayi and Riemann were quite bold when proposed and they challenged the established mathematical practices of the time. The point to note is that despite the standing of near-perfect Euclidean geometry for more than twenty centuries, efforts to check its soundness and generalization were taken in a professional spirit and results were assimilated in mainstream mathematics smoothly once they were found logically valid. This diversity of geometry has led to beneficial developments in many fields. An outstanding example of this is how Riemannian geometry paved the way for Albert Einstein to develop the "Theory of Relativity."

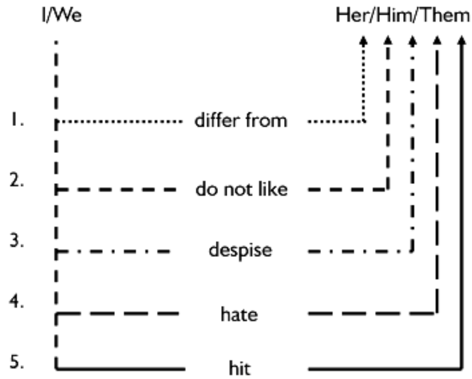
In broader terms the attitude of non-rigidity or acceptance of pluralism in mathematics has helped the subject in its advancement. The same holds true for the survival and progress of human beings. The underlying message is that different beliefs, rituals, life styles and cultural systems are necessary and should not be destroyed unless they cause irreversible damage to the ecosystem. Killing of those who live and conduct themselves differently is not justified on these grounds. It is pertinent to propagate this analogy from mathematics to a wider scale to deter killing for differing viewpoints or faiths as witnessed throughout the history and even currently in many places.

Compromise Programming

Killing to satisfy need or greed also occupies much of our history books. Scarcity of basic resources such as arable land, water sources and domestic animals to support physical survival caused innumerable battles among tribal groups until the establishment of relatively sustainable city states. This however was followed by long drawn out battles and wars to satisfy greed—annexing gold and other precious things possessed by others or to subjugate more lands and exploit their people for the advantage by the winner. Some of those campaigns also wore the cloak of settling ideology differences. Unfortunately, it is very difficult to draw a clear line between need and greed. Failure to resolve conflicts over resource distribution, however, has been a principal cause of human suffering at the core. This is now seen more prominently in many local and regional situations in the Indian Sub-Continent and East Africa to name a few.

It may be noted that most of these conflicts over resource distribution build over time. Absence or slow implementation of land reforms to assist landless labourers is one such cause of conflict. The adversarial feeling escalates if not checked before it is too late. Figure 1 shows the phenomenon of increasing intensity of hatred ranging from merely "not liking" to "killing" others to meet our perceived needs or goals. In practice, however, the process is not always a gradual five-step one as portrayed in Figure 1. One harsh incidence of considerable intensity can lead to a scene of carnage in no time. Close monitoring of such situations is necessary to initiate controlling actions. Transparency, promotion of reciprocation, and attitude of inclusiveness to avoid the spiralling growth of conflict is another necessity. Keeping the doors open for dialogue and negotiation is the key to avoid the stage of taking lives (Patkar, 2006).

Figure 1. Escalating Conflict Process



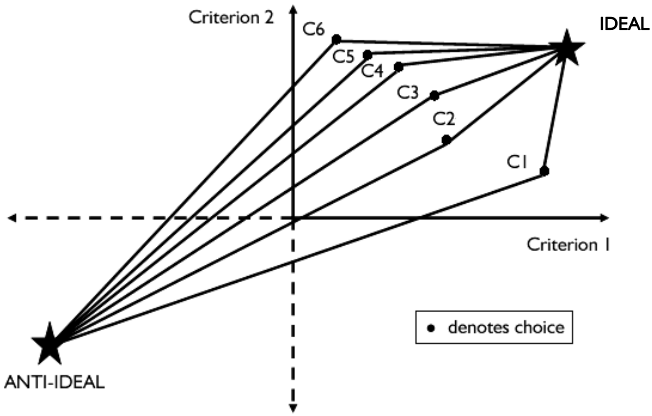
Conflicts of interest among parties, particularly over resources or ideologies, leads one group to pigeonhole others in the box of foe or rival. The corollary would be if the underlying noxious factor giving rise to conflict could be managed, occasions to deal in killing business would be reduced. A vast amount of serious writing ranging from philosophy to political science deals with this idea. In particular, variety of mathematical models from linear and non-linear programming, game theory and economics are devoted to this theme. Their use in dealing with distribution problems at a gross level is found to be fairly successful in many instances. However they have limitations in dealing with micro-level conflicts involving actual individuals charged with emotion.

One approach to tackle the issue is based on the principle of discovering a prominent alternative that could be acceptable to all the involved parties (Schelling, 1960). So conflict can be seen as absence of a prominent alternative (Zeleny, 1976; 1982). The theory of compromise programming works on this concept. It represents a family of techniques to address conflicts that may arise either due to several objectives (multi-criterion) or many stakeholders (multi-party). A compromise programming model usually captures viewpoints of the stakeholders for the available choices expressed, for example, in the form of ranking or attributes scores under different criteria. An ideal choice is to be conceived next. If that cannot be done independently, it could be constructed by assigning the best score or ranking on all criteria counts. Obviously it would not likely be realizable in real life. The proximity of available choices to this ideal is to be computed in the next step. This is done by constructing a suitable metric (e.g., by employing generalization of distance measuring formula of elementary co-ordinate geometry). The choices *closest* to the ideal according to the distance measure are the best possible compromise choices. Sometimes an anti-ideal is constructed by considering the worst possible features and in that case the choices *farthest* from it are the recommended solutions. Quite often a band of compromise solutions would emerge by considering ideal and anti-ideal choices together. In such cases some new criterion is to be applied to break the tie.

The process is illustrated in Figure 2 where six choices: C1, C2…C6 are compared on the basis of two criteria, namely Criterion 1 and Criterion 2. It is assumed that higher values on both criteria are to be preferred, such as safety and ease of operation. The ideal represents a choice characterized by the highest (positive) values according to these criteria. The anti-ideal represents a worst possible choice having the lowest (negative) values according to the same two criteria. They are depicted by a "star" in the second and third quadrant in Figure 2. Distance of each choice from both ideal and anti-ideal choices is determined by using elementary mathematical formula for distance calculation. It is seen that choices C3 and C4 are closer to the ideal than other choices while the choice C1 is farthest from the anti-ideal in comparison to other choices. The tie between C1, C3 and C4 could be broken by employing a criterion other than Criterion 1 and Criterion 2 used originally. In practice, the region bounded by the choices C1, C3, C4 and Ideal could also be explored to generate new choices or prominent solutions. It is clear that the method can be extended to multiple criteria and/or many parties and computer facility can be suitably employed for the involved calculations. The nature of a compromise solution so generated is such that participants would not usually prefer to deviate from it as that would lead to their own disadvantage. This binding capacity of the compromise programming solution is found useful in practice (Patkar, 2009; Zeleny, 1982).

It is clarified that compromise programming basically attempts to *resolve* the conflict. It is therefore not a complete cure, and conflict would surface at the first opportunity. Efforts obviously are needed to *dissolve* the conflict permanently. Generation of additional choices and making the decision process more inclusive and transparent are necessary for this purpose. Compromise programming however provides the vital insight about the situation, and necessary breathing time to work out better solutions and diffuse the tension. To put it differently it increases the threshold of tolerance on the part of the involved parties to a certain degree. We believe that compromise programming provides the methodological revolution envisaged by Paige to adapt methods of analysis and action suitable for bringing about nonkilling transformation (Paige, 2009: 78). To make parties willing to participate in this process still remains a big challenge. Perhaps a few demonstrations of compromise programming application to resolve some relatively less complex community level issues could generate the needed interest.

Figure 2. Ideal, Anti-Ideal and Choices



Other Mathematical Leads

Lack of foresight to comprehend the future consequences of actions, capacity to appraise them impartially, and questioning one's own beliefs are identified as, basic causes of discordant behaviour and attitude (Bell, 2004). Development of suitable methods under the discipline of Future Studies and prescribing guidelines accordingly for assessing the long term impact of punitive actions and to habituate people to periodically examine their beliefs and perceptions are very much needed. Though the United Nations through its various organs is largely pursuing these very points, the process has produced indifferent results due to various reasons. The outlook of letting go of our own mistakes and letting go of others' mistakes with a resolve not to repeat the same is to be propagated. The post-apartheid regime in South Africa is a shinning example in this context. Imparting training to develop necessary skill for this purpose should become an essential part of our education system besides sharpening analytical tools to fathom the underlying complexity of a conflict situation.

Mathematics, as currently taught in schools and colleges all over the world, is projected as an abstract entities manipulation process with the objective of attaining some utilitarian goal, such as increasing efficiency of a product or service. In short the operational part of mathematics is mainly emphasized. Several other important aspects are in general hardly brought to the notice of students. For instance, study of historical roots of mathematics in different cultures (i.e., ethnomathematics) reveals its rich potential to tackle a variety of conflict management problems (Ascher, 2002; Joseph, 1994). Making the students aware of the profound strength of mathematics for positive contribution along with its comprehensive ethics is the responsibility of both practising mathematicians and mathematics teachers (D'Ambrosio, 1998).

In psychology a conflict is generally defined as a situation where two or more motives are partly blocking each other and therefore discussion, persuasion and negotiation are prescribed to remove the cognitive difference. To assist this process generation of prominent alternatives holds the key as seen above. A program to develop full-fledged conflict algebra for examining the conflict under different perspectives and extending the power of compromise programming is one direction for further mathematical research (Zeleny, 1976).

The theory of a proportioning network provides one more framework to study human interactions mathematically. Various models under this theory examine the responses and counter-responses over time among two or more parties in a real life transaction. Different kinds of end states are predicted by this analysis. Those are determined by the nature and intensity of responses reflecting factors such as commitment to certain viewpoint and availability of information influencing the situation at a given point in time. These states are: a balanced state of more or less equal reciprocation, or an oscillating state where appropriate reciprocation is extended occasionally, or steady state where such reciprocation occurs as an exception (Zemanian, 1978a, 1978b, 1979). For instance, application of this theory for analyzing the phenomenon of offering a seat to an aged fellow passenger in a crowded city public transport bus over time clearly traces the decline of this normally expected civil courtesy (Modak and Patkar, 1984). The hardening of attitude escalating to killing in human dealings under different circumstances should be studied under this powerful analytical tool of proportioning network and its extensions to guide the design of preventive or diffusing measures.

More often than not a conflict situation is perceived quite differently by the involved parties. Naturally they attempt to find the optimal solution with regard to their own viewpoint. This results in distorted distribution of resources and benefits among different groups causing serious conflicts if not corrected soon. Mathematical models for analyzing such diverse optimality scenarios are available and their application can help to achieve amicable settlement in practice (Patkar, 1993; Zeleny, 1998, 2005).

Studying only some parts of a conflict and resolving them satisfactorily often is not sufficient because a total situation which is an aggregate of such micro-situations may still be leading to failure. A peculiar phenomenon of senescence through a feedforward mechanism may be at work (Patkar, 1993; Rosen, 1978). Ample scope exists to develop a suitable mathematical framework to anticipate and understand this process and suggest methods to track them in real life.

Traditionally game theory has been associated with framing tactics and strategies with regard to armed actions or any competitive situation in general. Its applications for addressing social issues also have received a major thrust (Brams and Taylor, 1999; Brams, Edelman and Fishburn, 2003; Rapoport, 1970). Further advances in game theory in forms such as metagame theory, hypergame theory, drama theory and confrontational analysis provide a rich variety of procedures to assess the degree of hostility under each round of action and reaction and put forward ways and means to avoid the breakdown (Bennett, 1977; Howard, 1971, 1999).

Likewise methods integrating subjective assessment and analytical techniques such as Analytic Hierarchy Process, Interpretive Structural Modeling and Generic Design Science which have been extensively used for addressing varied conflicts would prove useful to espouse nonkilling mathematics (Patkar, 1988, 2009; Saaty, 1980; Warfield, 1976, 1990). Allowing maximum public participation in the operation of these methods is a significant point of departure. Development of such tools is to be promoted because their use would be imperative for meeting the challenges of serious conflicts that are likely to touch everyone in future. Scarcity of water and food security would be some of the issues.

Support of Information and Communication Technology

Reform in mathematics teaching and education in general is one strategy to spread the message of nonkilling mathematics. However, a large segment of the population, particularly in developing countries, is still excluded from the formal education system. Informing and enlightening such individuals and communities needs urgent attention because they often provide the cadre for carrying out killing missions by different groups. Advances in information and communication technology (ICT) can play a crucial role in the explication process. For instance, globe-covering media such as television and the Internet could be employed quite effectively to this end. Mobilizing large-scale public opinion in the framework of compromise programming or any of the above interactive methods could easily be done by such ICT means (e.g., SMS system and web-based surveys).

Promotion of altruistic attitudes and behaviours is one theme that needs to be projected for instance to desist from killing and to counter usual selfish actions. By killing we get into a trap from which it becomes very difficult to escape; cooperation and reciprocity to help everyone should be highlighted (Patkar, 1991). Exploiting the vast reach and rich graphic capabilities of the ICT for a dramatic presentation of this process in terms of stories incorporating simple mathematics can make an immense impact. Suitable scripts and multimedia material are to be prepared for this purpose. Use of cleverly designed videogames can also reinforce this message especially among children and youth. Such productions could be done jointly by mathematicians and media experts.

Similarly, the false notion that by killing so-called offenders our suffering and problems would be reduced is to be expelled from the minds of the masses. One explanation to put forth could be that a phenomenon of conservation of human suffering in societal affairs may be at work (Patkar, 1988). That could again be presented by the imaginative use of mathematics and ICT. Examining different possibilities and pluralities would certainly be strengthened by such broadcasts, or webcasts, or multicasts.

Subject-dedicated web sites, blogs, chat groups and all such evolving ICT-based platforms can inform the mathematics community of their wider responsibility to promote non-killing mathematics and to share their concerns. For example, discussion of whether a moral commitment like the Hippocratic Oath would help in this direction can generate interesting suggestions.

Concluding Remarks

Conflicts in various geographical sectors are taking heavy tolls on human souls today. Preventing such killings and containing the conflicts should receive top priority. Tremendous scope for mathematics to contribute to building nonkilling society is envisaged in this setting. It can do so primarily in two ways, namely education and practice. One is to impress upon the students the necessity and usefulness of plurality in life by showing various developments in mathematics. Construction of non-Euclidean geometries presented here is one such example. Second is to apply suitable mathematical methods to address the conflicts and at least contain them if they cannot be completely eliminated. Initially addressing a local level problem through this approach is recommended. Based on this experience, higher order conflicts could be considered. Even appropriate mathematical formulation of a conflict situation can supply many new insights which can be pursued in different ways. Models from compromise programming discussed above can certainly serve the cause. Instead of humiliation or annihilation, promoting reconciliation among various groups to arrive at a solution is its basic strength. Only through repeated use of compromise programming and other such interactive techniques discussed in this paper can they be refined to become more effective.

The ICT can be employed to project the role of nonkilling mathematics innovatively on a global scale resulting in a benefit to everyone. On the other hand, the mathematics community would be made aware of its responsibility and encouraged to resist the harmful use of their subject expertise. Enlightened with such information about peace-supporting application of mathematics, various community groups can put pressure on decision makers to employ mathematical tools only for constructive purposes.

It is not an exaggeration to say that progress of mankind in general depends on the further development of mathematics, both fundamental and applied. And for the advancement of mathematics, prevalence of peaceful societal conditions plays a critical part. The message is loud and clear—our cherished dreams like inter-galactic travel and outer planetary colonization cannot be realized if mathematics is not focused to solve the higher order problems involved in such tasks. Directing mathematics inwardly against humanity for killing and extinction would be the greatest blunder of man. Rich dividends are expected by operations of addition, summation and integration rather than subtraction, elimination and division in human groups for addressing increasingly complex societal problems. Survival with dignity and advance on all fronts will be greatly assisted by nonkilling mathematics.

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Mathematics and a Nonkilling Worldview

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> It has not yet been sufficiently realized that present mathematical and scientific education is a hotbed of authoritarianism and is the worst enemy of independent and critical thought (Lakatos, 1976: 142-143).

Imre Lakatos, renowned philosopher of mathematics, was a young adult in Hungary during and shortly after World War II. He hid from the Nazis, taught Marxism in the underground movement, helped communism establish power and eventually fled the regime he helped to establish (Long, 2002). He knew authoritarianism intimately. His concern for the way mathematics and science are presented and their connections to authoritarianism, quoted above from his book *Proofs and Refutations: The Logic of Mathematical Discovery*, raises questions for educators who reject killing as a means of achieving any ends. These questions may be underscored because of the context in which he came to his conclusion about mathematics and authoritarianism. How does the teaching of mathematics promote authoritarianism? And, does this promotion support the idea that killing others is permissible?

I have reflected on questions like these for some time in my own significantly different context. I have enjoyed relatively peaceful political and social situations in a stable, relatively wealthy country, growing up in a Mennonite tradition known for rejecting the idea that wars can be legitimate: there is no context that can justify killing. Like Lakatos, I have focused my studies, research and teaching on mathematics, though my own focus has been on mathematics education. And, like Lakatos, I have come to the conclusion that mathematics is implicated in the development of authoritarian regimes, which can operate on a large scale, such as a dictatorship, or in subtle ways within a democratic environment. Two questions underpin much of what I do. What is the role of mathematics in violence? How can mathematicians and mathematics educators work for peace and against killing and other violence?

If I were asked to make a choice between developing good mathematicians or good citizens who respect and care for one another, there would be no question. I value nonviolence over mathematics. However, I believe that mathematicians and mathematics educators can work for peace and against violence, just as we can support violent worldviews in our work.

In this essay, I first clarify the focus of my attention—accessible reflection. Without discounting necessary reflection on how one's mathematics is used, I want to focus here on how we represent or depict mathematics. Second, I promote openness as central to nonkilling interaction. I refer here to Glenn Paige's (2002: 30) articulation of nonkilling: "a nonkilling society is characterized by no killing of humans and no threats to kill." Openness is an important characteristic of mathematics that is not always evident in mathematical representations. Third, I draw attention to the cultural characteristics of mathematics, as an example of openness. Fourth, I reflect on the dangers of society's excessive trust in mathematics.

Accessible Reflection: How do we Represent Mathematics?

Mathematics may seem innocent because it cannot be used directly to kill. But mathematics is a tool that can enable technologies that kill or lead to death. Yet another way in which mathematics may be implicated in violence is by encouraging or underpinning violence. I ask how the actions of mathematicians and mathematics educators might support a person's or a community's sense that killing and other violations of human rights are acceptable or even desirable. Without the will to kill, tools are generally not dangerous. Without the will not to kill, any powerful tool can be dangerous. I ask how people's experiences with mathematics can develop or support worldviews that either condone or reject killing and violence.

Mathematics is powerful. It enables us to model and thus visualize phenomena that the physical tools at our disposal cannot access. It enables our imagination to explore spaces that conventional wisdom scorns as unreal, impossible or insignificant. It facilitates the management and arrangement of data that exceeds human ability to sense. The list of its powerful qualities goes on. Because of its power, mathematics can be used both to expose and address social injustices and to underpin and sustain violence. Even mathematics that seems at first to work with imaginary spaces often proves relevant to real applications.

A problem for mathematicians interested in human harmony is that it is difficult, perhaps impossible, to predict how a particular mathematical innovation might be applied for good or for ill. Because of this difficulty, it seems to me unreasonable to expect mathematicians to accept responsibility for misuse of their innovations. However, they can still reflect on the possibilities their mathematics could open up.

I once attended a lecture given by a mathematician who explained her work on animal population modeling. In the question time, some mathematics educators (scholars who research the learning and teaching of mathematics) asked the speaker if she had considered the ethical implications of her mathematical modeling. She answered no, and remarked that this question is not one she had heard before. Many of the mathematics educators at this conference said they were agitated by her response because ignoring ethical implications is irresponsible. They felt that her unfamiliarity with the question pointed to a general lack of attention to this question among mathematicians. Reflection on the applications of one's mathematics could direct one's research agenda to explore areas that may underpin socially responsible understanding and innovation and to avoid areas that may underpin violence.

This concern relates to Ubiratan D'Ambrosio's (1994: 443) call for reflection on the importance of mathematics and science in this century's enormous technological advances.

> Humanity has seen the smallest reaches of imagination and talks about reaching the boundaries of the universe. And yet, this same century has shown us a despicable human behavior …Much of this paradox has to do with an absence of reflections and considerations of values in academics, particularly in the scientific disciplines, both in research and in education.

While I too would like the mathematician who had not thought about the ethical implications of her work to consider the ways in which her research is and might be used, I worry that it is too much to ask for her to accept responsibility if others use her innovations for harm. Even mathematics that is developed with the intention of supporting socially just innovation could be used to support technologies of violence.

Thus, while supporting the value of reflecting on the significant role of mathematics in killing and other human violations, I focus my reflection on a question that is within the grasp or control of mathematicians and mathematics educators: How do my representations of mathematics influence people's worldviews? In other words, how do people's experiences with mathematics develop worldviews that either condone or reject killing and violence? Mathematicians and mathematics educators may not have control over the ways in which mathematics is used, but we do have strong influence on the way our mathematics is talked about. In turn, the way mathematics is talked about influences the way people imagine themselves using it. In this essay I am less concerned about the mathematics that people do and more concerned with the way mathematics is represented for the public and for students at all levels (primary to tertiary). In the next section, I ask how mathematics might open attention to new perspectives and I reflect on this question in terms of a nonkilling agenda.

Mathematics and New Perspectives

> If I took alarm at the prospect
> of things spinning out of control
> (and I might
>   for they are
>   oh, I well might)
>   this refuge would tempt me.
> — Chandler Davis

These lines open "Cold Comfort," a poem by mathematician Chandler Davis (2008: 52). He offers his reflections on the comfort mathematics brings him in a world that he cannot control, as he recognizes the tension between wanting control and accepting the impossibility of control. Although mathematics often presents controlled situations, it also clarifies the impossibility of predictability and security.

This paradox is also represented in two of the six values identified by Alan Bishop as evident in mathematics. First, Bishop (1988: 151-152) identified *control*, which he connects closely with security: "Mathematics, through science and technology, has given Western culture strong feelings and sentiments…of security in knowledge—so much so that people can become very frustrated at natural or man-made disasters which they feel shouldn't have happened." Bishop contrasted this penchant in mathematics for right answers with a sentiment for *progress*: "Knowledge can develop" (1988: 152). Though there may be clear right answers to defined operations in a defined space, mathematicians develop new spaces or new perspectives on known spaces. Definition (defining operations, defining spaces) is important because the acts of defining and delimiting are central not only to controlling but also to clarifying opportunities for progress and to recognizing the limitless possibilities beyond these artificial boundaries.

The paradox between control and progress can be illustrated with an accessible example from school mathematics. When one looks for solutions to the equation $x^3 + x = x^2 + 1$, one might solve for zero and factorize to get (x

$-1)(x^2 + 1) = 0$. There is one solution, $x = 1$. Students learn a sense of satisfaction finding "the" solution to an equation. The solution ($x = 1$) can be verified, and sound reasoning can be applied to explain why $x^2 + 1$ cannot equal zero: the square of a number is positive, so adding a positive integer cannot result in zero. The one solution exemplifies control. However, there is only one *real* solution. Until students are introduced to imaginary numbers, they see only one solution. With the introduction of imaginary numbers, new possibilities come to light. Now there are three solutions; x could equal 1, i or $-i$. The point is that the closed, predictable domain of real numbers was developed by mathematicians and has been promoted by mathematics educators, but this closed, predictable domain was also blown open by imaginative mathematicians. Now the complex number domain is closed. Or is it?

Mathematics has a strong history of opening up new ways of seeing and analyzing the world. At the same time it has a strong sense of predictability: 2 + 2 is always 4. How does mathematics get this reputation for control and predictability when the history of mathematics is replete with examples of people introducing new perspectives that often turn past knowledge and perspectives on their heads?

Along with my colleague, Beth Herbel–Eisenmann, I have been investigating this question for some time. It is not the orienting question of our research. Rather, we have sought to describe the way mathematics discourse works in school mathematics classrooms, but the results point to the question stated above. Mathematics tends to be presented as predictable, controlled and closed even in environments that seem to have been influenced by mathematics teaching reforms that promote openness.

In a study of secondary mathematics classroom discourse we used corpus linguistics software to identify in diverse classroom contexts communication patterns that appear again and again (Herbel-Eisenmann and Wagner, 2010). (Corpus linguistics is the study of large bodies, or *corpora*, of spoken or written text.) We found that the most common recurring word patterns encoded what linguists call *stance.* Stance patterns communicate personal feelings, value judgments and attitudes. Recurring stance patterns are common in other corpora that have been studied, but in our analysis of secondary mathematics classroom communication we found unique stance structuring. The stance patterns that are characteristic of mathematics classrooms were structured by phrases that show high confidence. Linguists refer to this as high modality. These included phrases that assume there is one way of doing things and the speaker knows the way. Such communication patterns suggest that mathematics compels certain actions and restricts others—for example, "you need to," "we need to," "you have to" and "we have to" are said again and again in mathematics classrooms. Other phrases uniquely prevalent in mathematics classrooms show confidence that the correct path is already known; the result is predictable—for example, "you are going to," "we are going to" and "so we're going to" can be heard in mathematics classrooms regularly.

In order to change a control-oriented classroom to one that invites diverse perspectives, it will not work simply to try to change what we say as teachers or instructors. We say things like "we have to" and "we are going to" because the mathematics that we are doing is already known. We are doing closed mathematics. In order to structure a classroom that welcomes diversity, we have to change what we have students do. Then the words we say will reflect this openness. We have to change away from merely teaching procedures and giving exercises to develop these controlled skills, and change to engaging students in investigation of open-ended questions. Giving students the space to investigate mathematics may require reworking curricula to focus on objectives that relate to developing students' understanding of the processes of mathematical discovery instead of on objectives that comprise repetition of known procedures. John Mason's book, *Thinking Mathematically*, provides a good place to start thinking about the kind of mathematics that might help students to think differently about mathematics. But even within a curriculum that focuses on known procedures, one can teach by giving students problems before giving them procedures for solving these problems. This is called problem-based learning. Students develop better understanding with this approach. They also learn to appreciate both the insights they gain from their peers' perspectives and the beauty of efficient procedures that have been developed over time.

The key question for educators interested in nonkilling is this: Should mathematics be presented as closed and predictable or as open and imaginative? Taking a stance against killing in its various forms, which is not without controversy, does not make the question easy. Here I turn to a more personal voice to recognize my awareness that others have significantly different views on this moral question. I suggest that there is danger in presenting mathematics as closed and controlling. When we equip students and others with tools that appear to make control possible and appear to be predictable enough that we can be confident in one right answer, we may close off for these people their willingness to accept diverse views. If there is a social view that rigorous mathematics and scientific processes make it possible for us to decide ultimately what is right, all people who do not agree with this "right" decision are rendered "wrong." What do we do with people who are wrong?

In schools, including universities, we assign them failing grades, giving them the chance to try again and "get it right" or be relegated to paths with limited opportunities. Outside of schools, what do we do with people who are wrong? Ignore them? Marginalize them? Fight against them? Kill them?

I do not think it is a stretch to say that the habits of mind formed in school are carried into social practice. However, I am aware that there are other discourses that are complicit with mathematics education in developing the idea that one can be sure about being right and about others being wrong. Various religious traditions (including my own) seem to develop this kind of closed view of the world, for example.

An alternative to developing a worldview fixated on security and control is to show how new perspectives, though sometimes uncomfortable and surprising, bring richness and new understanding. Mathematics has a rich history of examples of the beauty and value of new perspectives. When we work with students or represent our work to the public, we can point to such examples from history and from our own experiences to demonstrate the value of considering new perspectives. Further, we can lead students and others to explore rich mathematical landscapes in such a way that invites their imagination.

Mathematics and Culture

> For here, it seems, is a structure that was erected without a scaffold: it simply rose in its frozen majesty, layer by layer! Its architecture is faultless because it is founded on pure reason, and its walls are impregnable because they were reared without blunder, error or even hesitancy, for here human intuition had no part! In short the structure of mathematics appears to the layman as erected not by the erring mind of man but by the infallible spirit of God. The history of mathematics reveals the fallacy of such a notion (Dantzig, 2005[1930]: 188).

Tobias Dantzig's comment on the difference between the image of mathematics and its history appears in his historical account of the development of number. In this section, I will question representations of mathematics that suggest it is culturally neutral. The tension of cultural neutrality versus cultural embeddedness relates closely to the tension between control and progress, as I will point out later in this section. I will argue that a productive way of drawing attention to the cultural nature of mathematics is to pay attention to and talk about human decisions in mathematics. Recognizing the human element in mathematics draws attention to its contingency on human experience and thus its connections to the cultures in which these humans developed the mathematics.

There is another tension at play when we recognize that all mathematical ideas arise in particular cultural contexts and contribute to those cultures. Seeing mathematics as cultural may seem to be at odds with the abstract nature of mathematics, with its characteristic move to establish truths that are contingent neither on the person nor on the person's historical, geographical, cultural or disciplinary place. However, abstraction is a human action, performed for particular reasons that relate to the person's current place in their world. Similarly, applications of mathematical abstraction (applied mathematics) are human moves to bring context-independent knowledge into contexts. Generalization and abstraction are features of mathematical thinking that have their place in thoughtful human problem solving. There is value in asking what is always true regardless of context but there is also value in asking how results drawn from such generalization and abstraction can be applied or not applied to any given human problem.

There is a movement among some mathematics educators to recognize the cultural nature of mathematics. Ubiratan D'Ambrosio is at the forefront in promoting reflection on connections among mathematics, the sciences and human problems. He is credited with initiating the movement to study cultural specificities in mathematics. He called such study *ethnomathematics*. Much ethnomathematics research is focused on identifying mathematics that is not reflected in mainstream academic traditions. However, it is important to note that ethnomathematicians claim that all mathematical ideas arise from humans addressing their issues or problems in particular cultural milieux. It is not only non-academic mathematics that is cultural. We might enjoy experiencing cultures with travel, but we should not forget that our home context is also a culture, equally strange to others. When we live in a dominant culture it is easy to forget that. Similarly, academic mathematics traditions are so dominant that it may be easy to overlook the fact that they are culturally situated.

The unique mathematics in a particular culture expresses itself in the focus of people's thoughts or obsessions, and also in the language and other symbols developed to represent these thoughts and obsessions. For example, some cultures have developed what may appear to be merely rudimentary number representations. One might be tempted to judge the level of development in a culture by applying the needs and standards of one's own culture, but that kind of judgment rests on privileging one's own culture above others.

In conversations with some Mi'kmaw elders (from an Aboriginal community in Canada), I learned that specific number words were mostly unnecessary for much everyday mathematics. When they described the choices and calculations made when preparing a meal, the actual number of potatoes someone would need to collect for the meal was not as important as the volume because individual potatoes vary considerably in size, especially when they are not graded for size and quality as they are in most modern grocery stores. The number of potatoes is unimportant compared to the amount or volume of potatoes. The situation was similar for collecting wood: it would be meaningless to send someone into the forest to get two pieces of wood without considering the size of the pieces. Thus there seems to have been little need for a well-developed number system. However, the Mi'kmaw language does have well-developed numbers. Lisa Lunney Borden (2010) has noted that number appears more in games in this community than in practical applications. Evidently, there was something in this community that set it apart from other cultures that did not need to develop very high number systems.

In the Mi'kmaw culture, and in others—e.g., Macpherson's (1987) description of an Inuit child's mathematics—quantity work is more spatial than it is numeric. Both number and volume measure can be relevant in quantity work, but the cultural context dictates which is most relevant. In a context obsessed with standardization, numbers are most appropriate because objects are organized and distributed according to these standards. In a context where little is standard, there are fewer units and thus much less need for counting. If judging cultures were our goal, we may think about the value of standardization. In our modern world, standardization facilitates far-reaching trade. Thus it is connected to colonization and also to increasing cultural interaction. Alan Bishop (1990) claimed that technologies for recording and manipulating large numbers are connected to cultural imperialism, and thus to widespread global violence, which again connects mathematical innovations to violence. As stated earlier, such connections are significant, but I want to focus my reflection more on the way mathematics is represented than on what procedures it makes possible. However, I realize that it may be difficult to separate these two.

Some years ago, I heard a fascinating interview with mathematician Erik Demaine on public radio that exemplifies how the human and cultural aspects of mathematics can be shown to the public (November 1, 2003 on *Quirks and Quarks*). This interview stood out for me because Demaine described the development of his interest in paper folding, and he connected his work to thousands of years of origami history, thus revealing the human and cultural nature of mathematics. He talked about what mathematicians have figured out and what remains unknown in his area of interest, and thus pointed to new opportunities for others who could bring their perspectives to these problems. And he talked about scientists who have been using his mathematical innovations to address their technological problems in space exploration and understanding protein molecules. Thus he connected his work again to humans using mathematics to confront particular problems in their cultures. Demaine's interview is an example of the kind of representation of mathematics that I think can change the way the public sees mathematics.

The key question for educators interested in nonviolence and nonkilling is this: Should mathematics be presented in a way that recognizes the cultural particularities of its origins and development or should it be represented as purely logical and outside of human experience? Here again I turn to a more personal voice to recognize my awareness that others would have significantly different views on this moral question. I think it is clear enough that mathematics is cultural and that it is generally portrayed as being free of culture, so the question really asks whether anything should be done to change the way it is being portrayed. Like the tension between control and progress, the question of culture connects to the distinction between being open and closed to new perspectives. If mathematics is portrayed as free of culture, then one privileged point of view dominates. If mathematics is portrayed as cultural, different possibilities are acknowledged and even valued. When we value each other's points of view, we do not often resort to violence.

Representing Mathematics for Nonviolence and Nonkilling

> The mathematics tells truth about the world.
> We are its ventriloquist, yet
> some words it won't let us put in its mouth.
> — Chandler Davis (2008: 53)

In the same poem I quoted earlier, Davis raises an interesting question about mathematicians representing mathematics. In a sense, mathematicians and mathematics educators must represent mathematical ideas in certain ways because otherwise the ideas would be misrepresented. Generalizations that are shown to be true regardless of context need to be reported in that way. This means that it is necessary to describe control in representations of mathematics. These aspects of mathematics will appear to be independent of culture. It is inescapable that our speech would refer to predictability and not refer to cultural differences when we talk about known procedures in defined spaces. For example, when we add sums of money, the result should be dependable. The result should not depend on the culture or position of the person doing the adding. Mathematics is supposed to be dependable and nondiscriminatory. This is an example of mathematics contributing to social justice.

However, not all representations of mathematics need to be focused on these generalizations and known procedures. We can also draw attention to the human stories that are part of these generalizations and established procedures. When we talk about our mathematics we can talk about decisions we made and reflect on how we came to those decisions. And when we talk about others' mathematical innovations we can set those innovations in their cultural contexts. In short, we can reveal the humanness of mathematics and talk about the connections between the mathematics we talk about and the cultural milieux in which it has developed.

Further, even the use of generalizations and known procedures always appears in a particular cultural context. Thus culture is at work. Yes, the result of summing amounts of money should be dependable, but there was a human decision to add those particular amounts of money in that particular time. Though the result is dependable given the inputs of the procedure, the result is still dependant on the numbers used in the procedure and in the choice of procedure.

Thus there are further implications of revealing the human, perspective-embracing and cultural aspects of mathematics. When, on the other hand, we suggest that mathematics is values-free or independent of culture we tacitly render rhetoric that uses mathematics as being above reproach. It is possible to make this suggestion explicitly—to argue that one's claim is above question—but I believe that the message is even more powerful when it is subtle, when the human choices that are part of mathematics are obscured. If I make a claim explicitly, I invite debate: if I say "mathematics is above critique" I tacitly raise the question "Is it in fact above critique?" But when we all talk about mathematics as if it is sure, secure, predictable and free from human particularities, others are unlikely to think about the alternative, namely that mathematicians regularly challenge each other and regularly develop new ideas that seem to break the old rules, and that people use mathematics for their particular agendas.

Why is it dangerous to develop the sense that mathematics is above critique? If it is taken as above critique it can be a powerful tool for manipulating people. Leaders of social change in politics, critics of politics, advertisers, social justice advocates and any others who want to convince people of something can and do use mathematical tools to press their points. Often, such rhetoric is used to justify decisions about who should live and who should die. But the public is ill-equipped to recognize that mathematics is being abused because of the perception that it cannot be abused. If mathematics appears secure and perfect, claims resting on mathematics are beyond critique.

Those who resist mathematics instruction and representation that invite diverse approaches risk encouraging intolerance of diversity in the human realm. Those who favor mathematics-informed abstraction in policy may insulate stakeholders from feeling the human implications of their policies. By contrast, mathematicians against such violations can change the way the world sees mathematics. Changing the face of mathematics can make real change in the world because so much is now seen through a mathematical lens. This mathematical lens was built by humans, and can be reshaped by humans.

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A Nonkilling Mathematics?

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> But nothing will ever quench humanity
> and the human potentiality to evolve
> something magnificent out of a renewed chaos.
>
> (D.H. Lawrence, 2001)

Nonkilling is the magnificent scenario we are struggling for. I want to envisage a road that makes Lawrence believe in man.

Political scientist Glenn D. Paige published, in 2002, a pioneering book on *Nonkilling Global Political Science*, featuring a very provocative and basic chapter entitled "Is A Nonkilling Society Possible?" In it Paige says:

> The structure of society does not depend upon lethality. There are no social relationships that require actual or threatened killing to sustain or change them. No relationships of dominance or exclusion—boundaries, forms of government, property, gender, race, ethnicity, class, or systems of spiritual or secular belief—require killing to support or challenge them. This does not assume that such a society is unbounded, undifferentiated, or conflict-free, but only that its structure and processes do not derive from or depend upon killing. There are no vocations, legitimate or illegitimate, whose purpose is to kill. Thus life in a nonkilling society is characterized by no killing of humans and no threats to kill, neither technologies nor justifications for killing, and no social conditions that depend upon threat or use of lethal force (p. 30).

A document elaborated by an international group of scientists, convened by the National Spanish National Commission for UNESCO in Seville, Spain, in 1986 and adopted by UNESCO, became known as the *Seville Statement on Violence*. In the last paragraph, it claims that:

> Just as wars begin in the minds of men, peace also begins in our minds. The same species who invented war is capable of inventing peace. The responsibility lies with each of us.

In the 8th World Summit of Nobel Peace Laureates, conveyed in Rome in 2007, participants produced the *Charter for a World without Violence*, which states:

> We are convinced that adherence to the values of nonviolence will usher in a more peaceful, civilized world order in which more effective and fair governance, respectful of human dignity and the sanctity of life itself, may become a reality.
> In implementing the principles of this Charter we call upon all to work together towards a just, killing-free world in which everyone has the right not to be killed and responsibility not to kill others.
> To address all forms of violence we encourage scientific research in the fields of human interaction and dialogue, and we invite participation from the academic, scientific and religious communities to aid us in the transition to nonviolent, and nonkilling societies.

I agree with the *Seville Statement on Violence* in accepting that I am also responsible for inventing peace and, as invited in the *Charter for a World without Violence*, I join Glenn D. Paige in committing myself to the enormous task of participating in the effort to create a World society in which there is no killing of humans and no threats to kill.

The great challenge which I face in writing this chapter is how, as a mathematician and mathematics educator to act to fulfill this commitment. How to go beyond the humanitarian dream? I believe an academic quest of the nature and history of mathematics may be helpful. This will be the focus of this chapter.

Introduction

As Peace Educator Leah Wells once said, "Violence comes from fear, fear comes from incomprehension, incomprehension comes from ignorance … we eliminate ignorance with education." To recognize, to respect and *not to fear* different values is the way to eliminate violence.

Education is a practice present in every culturally identified group. The major aims of education are to convey to new generations the shared knowledge and behavior and supporting values of the group, and, at the same time, to stimulate and enhance creativity and progress.

Let us consider groups of individuals who share modes and styles of knowledge and behavior, supported by a system of values, which were generated and accumulated throughout a common past. This characterizes a culture. Thus, a culturally identified group, be it a professional guild, a family, a community, a nation, shares sets of modes and styles of knowledge and behavior and values, embedded in traditions, which support knowledge and behavior. Knowledge, behavior and values which come from the past justify present behavior and, at the same time, entice and make possible the advancement of knowledge. Inevitably, the supporting values also go through permanent revision. This is the essence of progress.

The phenomenon of globalization leads us to consider a much larger group, indeed the total group of humankind. This leads us to envisage a universal culture. The major challenge is to recognize shared knowledge and behavior and supporting values for this total group, that is, for humankind. This asks for universal and transcultural knowledge, behavior and values. Examples of transcultural and universal knowledge are mathematics and the sciences in general. Modern, euphemistically called civilized, behavior, as expressed in manners, in dress, in the appropriation of technology, particularly the media, is advancing worldwide as universal behavior. A strong force of resistance is, as it has historically been, the systems of values.

Education has been focusing on knowledge, behavior and values of culturally identified groups and on past struggles for keeping the identity of the group. The violent facet of the struggles has dominated the historical narratives within education. If we accept the initial premise that action in the present reflects the past, it is undeniable that education has been favoring violence. The historical narratives are impregnated with hostilities and atrocities, and emphasize moments of success or failure. Although the moments of temporary success are sometimes marked by efforts to build up new styles and modes of knowing, behaving and accepting different values, these efforts have not been deserving attention in history education.

Every human being experiences biological, physical, social, psychological, spiritual needs and also wants. A road to peace is to achieve a balance between needs-wants and rights-responsibilities. Education for peace must consider the realms of inner peace, social peace and environmental peace, paving the way to military peace. These four are intimately related. To achieve peace between human beings, we must understand how man is integrated in nature and we must respect the equilibrium that exists in nature. This means that man must be in peace with the environment. Taking advantage of natural resources allows a few to accumulate wealth which, perpetrated at a structural level of the economy, generates social injustices, which is a factor that causes violence and killing.

In this chapter I will discuss mathematics, the earliest and most recognized universal system of knowledge. As it has been said by historian Mary Lefkowitz, "the evolution of general mathematical theories from those basics [mathematics of Egyptians, Sumerians and others] is the real *basis of Western* *thought* (emphasis added)."[1] History shows that Mathematical ideas have been expropriated by the Arts, Religions, Sciences and, in modern civilization, by the technological, industrial, military, economic and political complexes. Mathematics and mathematicians benefitted, and continue to draw resources from, these complexes, relying on them for the material bases of its continuing progress. I will also discuss the origins of mathematics and how a set of universal values, essential for peace, is intrinsic to mathematics.

I raise many issues, leaving most of then unanswered. This text is an introduction to a large and ambitious program of looking into mathematics as the real basis of civilizations; hence into the relations of mathematics with the arts, religions, sciences, economics, politics and architecture and urban life; hence with *peace*.

To achieve peace is essential for the survival of civilization. We are a threatened species. When I refer to peace, I am concerned with peace in its several dimensions: *inner peace*, *social peace*, *environmental peace* and, of course, *military peace*. Violations of peace in all these dimensions permeate the history of the world.

Violations of peace in all dimensions are frequently shown in the media and are dramatized in the arts. The Academy of Motion Picture Arts and Sciences recognized the violation of inner peace in American society by granting an Oscar to the movie *American Beauty*, which denounced this situation. Research institutions such as The World Watch Institute and many nongovernmental organizations systematically denounce violations of Social Peace and Environmental Peace.

Violations of Military Peace, that is, the insane practice of war, are a recurrent theme of the artistic, religious and scientific discourses. The impact produced by Picasso's "Guernica" synthesizes dramatic visualizations of the horror of wars in literature, music, photography and the plastic arts. Appeals to sanity and to stop war are frequent. The exhibit "Thermonuclear Garden," installed by Sheila Pinkel in several cities of the United States from 1982 to 1992, is an example of appeal to the American people to protest against production and export of weapons. Ecumenical meetings all over the world call for forgiveness and tolerance, love and harmony. And scientists lead the call for a stop to the insanity of war. Most pungent is the appeal of Albert Einstein and Bertrand Russell in the Pugwash Manifesto, 1955: "We appeal, as human beings, to human beings: remember your humanity, and forget the rest."

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[1] Interview given to Ken Ringle, *The Washington Post*, June 11, 1996.

The Pugwash Movement or Pugwash Conferences on Science and World Affairs, which was awarded the Nobel Peace Prize for 1995, has the motto "Thinking in a new way." Indeed, to go beyond wishful thinking and inspiring discourses, some bold, innovative action is needed.

I have a utopia: a world in peace! We need utopias in the sense given by Karl Mannheim, who sees utopia as the substratum of will. And will guides our actions. Mannheim says:

> The disappearance of utopia brings about a static state of affairs in which man himself becomes no more than a thing. We would be faced then with the greatest paradox imaginable, namely, that man, who has achieved the highest degree of rational mastery of existence, left without any ideals, becomes a mere creature of impulses. Thus, after a long tortuous, but heroic development, just at the highest stage of awareness, when history is ceasing to be blind fate, and is becoming more and more man's own creation, with the relinquishment of utopias, man would lose his will to shape history and therewith his ability to understand it (1954: 236).

Global Responsibility

This paper basically deals with the global responsibility of Mathematicians and Mathematics Educators. The guiding question is, "How do we fulfill, as Mathematicians and Mathematics Educators, our commitments to humankind?"

To be highly provocative, I invite people to reflect on the embarrassing fact that people who have attained a high level of cultural development, particularly excellence in Mathematics, have performed the most despicable human behavior in recent times. Let me make it very clear that this is not an insinuation of an intrinsic malignity of Mathematics. But it is clear that Mathematics has been an instrumental companion in the historical events that we all deplore. Let me also make very clear that I see Mathematics playing an important role in achieving the high humanitarian ideals of a new civilization with equity, justice and dignity for the entire human species, without distinction of race, gender, beliefs and creeds, nationalities and cultures. But this depends on the way we understand how deeply related are Mathematics and human behavior. Mathematicians, Historians of Mathematics and Mathematics Educators rarely consider these questions.

It is undeniable that Mathematics is well integrated into the technological, industrial, military, economic and political systems of the present world. Indeed, Mathematics has been relying on these systems for the material bases of its continuing progress. We may say that Mathematics is intrinsic to today's culture. Thus we are led to examine the History of Mathematics as related to World History.

In order to appreciate the real significance and importance of Mathematics in different cultures and in different times, it has to be viewed through what might be termed a "cultural lens." It is hoped that this approach will illuminate many areas of mathematical thought and indicate new directions of research. As a result, we may better understand the implications of mathematical research, its contents and its pedagogical methodologies, for the achievement of peace in its several dimensions: military peace, environmental peace, social peace and inner peace. This is essential for building up a civilization that rejects inequity, arrogance and bigotry, which are the behaviors which initiate and support killing. Paradoxically, the intense rejection of these behaviors sometimes are, themselves, arguments favoring killing and violence.

As a mathematician proposing strict nonviolence, it is very difficult for me to understand why and how the recognized pacifist Albert Einstein sent to President Franklin Delano Roosevelt, on August 2' 1939, the decisive letter to build an atomic bomb, that killed thousands of Japanese civilians, families, elders and children and deflagrated the Cold War. In his letter, Einstein says:

> Some recent work by E. Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration.

The United States was then neutral. After the Japanese attack on Pearl Harbor on December 7, 1941, the United States declared war on Japan, and Germany, drawn by its alliance with Japan, declared war on the United States. But the atomic bomb project was well under way.

This is supported by the concept of being prepared for a just war. The argument is that the destruction and killing of civilians is necessary, although regrettable. This argument is as old as civilization, and continues to be employed to this day.

Can the argument of just war be supported? In the name of what? The maxim "For the winners and just, medals and paradise; for the losers and wicked, scaffolds and hell" seems to be universally accepted. The concept of *bellum iustum* is as old as humankind. Laurens Winkel synthesizes it well:

> The term *just* war is misleading, though, suggesting as it does that at some point in time there has been or may be a conflict in which one side is morally perfect—as if there is an ideal or precedent that may serve as a role

> model for future just warfare. Yet, historically the concept of holy war has made precisely this claim, and holy war apologists have rendered such conflicts by analogy with heavenly battles between the forces of light and darkness; and even e.g. the cold war concept of ideological war was often expressed in similar terms (1999: 6).

The Prevailing Attitude

It is not sufficient to say, as it is common in our profession—indeed, in every profession—that we are fulfilling our commitment and responsibility to humankind "By doing good Mathematics" or "By being a good Mathematics teacher." Doing good mathematics should be complemented with the question, "What will be done with the Mathematics I am helping to develop?" And a good mathematics teacher must always be asking, "How will my students perform? Will they be conscious of their moral commitment in their professional life?" Our responsibilities include the uses society makes of our intellectual production and what is the influence we have in the behavior of future generations.

It is naïve or sarcastic to say, as G. H. Hardy has said, that:

> Real mathematics has no effect on war. No one has yet discovered any warlike purpose to be served by the theory of numbers... So, a real mathematician has his conscience clear; there is nothing to be set against any value his work may have; mathematics is, as I said at Oxford, a 'harmless and innocent' occupation (1967: 140).

Indeed, the theory of numbers is a fascinating subject, even for children in early schooling. But what bothers me is that the most attractive jobs for specialists in the theory of numbers are offered by the Department of Defense. It is one of the most important resources for military purposes.

The possibility of final extinction of civilization on Earth is real. Not only through war. We are now witnessing an environmental crisis, mounting social crises in just about every country and, above all, the recurring threat of another World War. I cannot accept that it is normal to solve regional conflicts by military means and that isolated wars can be tolerated. Mainly as retaliation, which produce a chain of retaliatory actions, inevitably chastising innocents who are conveniently used as human shields, thus serving as a very efficient argument for cooptation. Although isolated, the violence and violation of human dignity going on in these conflicts are abhorrent. It is perturbing that discourses of "pacifists" open the way for necessary wars and just wars. Even in Tao Te Ching, #31, we read:

> Weapons are the tools of violence; all decent men detest them. Weapons are the tools of fear; a decent man will avoid them *except* (italics mine) in the direst necessity and, if compelled, will use them only with the utmost restraint.

History has shown us that regional and limited conflicts eventually lead to larger involvement of nations. Escalation paves the way to World War.

Even more alarming, because it is a subtle violation of peace, is the lack of inner peace of individuals, leading to drugs, nihilism and violence.

To survive as a species we have to achieve peace in its several dimensions: Inner Peace, Social Peace, Environmental Peace and Military Peace. This means peace with dignity. In a correspondence to Albert Einstein, Sigmund Freud said:

> perhaps our hope that these two factors—man's cultural disposition and a well-founded dread of the form that future wars will take—may serve to put an end to war in the near future, is not chimerical. But by what ways or byways this will come about, we cannot guess.[2]

We all, particularly mathematicians, have a responsibility to find these ways. As it was mentioned earlier, Mathematics is well integrated into the technological, industrial, military, economic and political systems and mathematicians have been relying on these systems for the advancement of their professional career and for material reward.

Rare, but exemplary, is the attitude of Derek Smith who in 1992, was working in speech recognition for Texas Instruments. When he learned that the results of his work were playing a role in the control systems of an anti-radar missile developed by the Pentagon, he decided to quit his job and joined, thanks to his expertise, a research group to model the immune system recognition of influenza viruses (*Science*, April 18, 2008, pp. 310-311).

Cooperative subservience is not restricted to specialists in Science and Technology. They are found in Economics, Communication, even in Philosophy—indeed in all fields of academic specialties and professions. It is extremely difficult to avoid. The cooptation strategies are subtle, and sometimes, intimidating. Ideological and even academic zealots play a fundamental role in this.

If, as Mathematicians and Mathematics Educators, we try to answer the challenge of Freud to Einstein, it is natural for us to reflect on our personal role in putting an end to and avoiding future wars. According to Freud:

> Thus it would seem that any effort to replace brute force by the might of an ideal is, under present conditions, doomed to fail. Our logic is at fault if

[2]http://www.public.asu.edu/~jmlynch/273/documents/FreudEinstein.pdf (27/01/09).

> we ignore the fact that right is founded on brute force and even today needs violence to maintain it (op. cit., p. 12).

The issues are essentially political. There has been reluctance among mathematicians, and to a certain extent among scientists in general, to recognize the symbiotic development of mathematical ideas and models of society. Mathematics has grown parallel to the elaboration of what we call Modern Civilization. Historians amply recognize this. Particularly explicit on this is Mary Lefkowitz, as quoted in Note 1 above, in recognizing that mathematics is universal.

We cannot disregard the fact that *the most universal problem*—that is, survival with dignity—must have much to do with *the most universal mode of thought*—that is, mathematics. I believe that to find the relation between these two universals is an inescapable companion to the claim of the universality of mathematics.

Our commitment implies that we must adopt a broad view of the world and of humankind in general. This is possible through a reflection about the future and a broad perception of the state of the world, which is disturbing. It is a general feeling that human behavior has not been ethical. In particular mathematicians and mathematics educators have not been explicit about comprehensive ethics guiding their practices. An ethics of responsibility is needed. But, given the universality of mathematics and of its effects, this ethics must go beyond professional codes of behavior and professional ethics, such as the Hippocratic Oath.

It is natural to express discontent with the state of the world by chastising Science and Technology, which are recognized as the embodiment of modern society. Science and Technology are thus blamed for the malaise of humanity. Mathematics is, obviously, directly affected by this criticism.

The challenges and counter-challenges we are witnessing reflect a defensive posture that is growing to contain the wave of discontent. For many generations, access to facts has been controlled by moral and material instruments, among them norms and codes, language and literacy, and all organized as systems such as religions, sciences, languages, and technology. Reminiscent of the ideological zealots of the Senator Joseph McCarthy era, academic mobbing is a powerful control instrument. Paradoxically, the same instruments, which were fragmentarily constructed to preserve the prevailing order, became so complex that they are no longer effective and became increasingly permeable. An old Spanish refrain says "*Cría cuervos y te sacarán los ojos*" ["Raise crows and they will peck your eyes out"]. The creature escapes the control of the creator. The fall from grace of Senator McCarthy, as well as metaphors such as Adam, Frankenstein, Hal of *2001*, and the androids of *Blade Runner*, all point in this direction. Our hope is that a new thinking in Science, mainly in Mathematics, will be able to go through the control mechanisms.

The Reaction to the Challenge

Rasing questions is sometimes interpreted as opening doors to anti-science and irrationality. In his recent book, Carl Sagan cautions about the lure of new directions in inquiry. In his denouncement of the "new Dark Age of irrationality," Sagan says:

> Each field of science has its own complement of pseudoscience. Geophysicists have flat Earths; hollow Earths, Earths with wildly bobbing axes to contend with, rapidly rising and sinking continents, plus earthquake prophets (1996: 43).

It is misleading to denounce discontent as such. Indeed, these conflicting postures have led to the so-called "Science War." Research done by Sociologists of Science has been more focused on the relations of Science and Society. But the new field of Social Studies of Science has been criticized. Alan Sokal drew much attention to the theme in a hoax published in one of the cherished journals of postmodern critics.[3]

The polemic thus started is not different from those focusing on afrocentrism and feminism. The polemics surrounding the discussion of scientific knowledge by postmodern critics reveal the real issue of the subordination of Science, which is a political one, that goes much beyond national arenas. Ideological labels are often subtly used to justify fundamentalism in the defense of the prevailing academic order. This is very well illustrated by the fact that Sokal's hoax was used, a few weeks after its publication, by Brazilian Congressman Roberto Campos to support his political rightist harangue. A few days later, Alan Sokal published a reply to Congressman Campos in the same influential Brazilian newspaper, explicitly criticizing

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[3] See the polemics around the article by Alan Sokal published in *Social Text*, criticizing postmodernism, particularly Sociologists of Science, and also the article by Steven Weinberg: "Sokal's Hoax," in *The New York Review of Books*, August 8, 1996, pp.11-15. Particularly interesting are articles by Sullivan (1996) and Harrell (1996). It is illustrative to look at the exchange of letters between Noam Chomsky and Marcus G. Raskin in the book by Marcus G. Ruskin and Herbert J. Bernstein (1987: 104-156).

Campos as a rightist and declaring himself as a leftist. Another example is the television debate between candidates Clinton and Dole on October 6, 1996, during which Senator Dole frequently used the word "liberal" to attack the policies of President Clinton. There is a danger that these polemics result in the deviation from the main objective, which is to "condemn injustices and inequities of the capitalist system and try to eliminate or, at least, minimize them," using the same words of Alan Sokal, which contradict his posture in deflagrating a total Science War.

To challenge scientific, religious, socio-political and historical knowledge does not mean to retrogress. It has always been a coherent response to the state of society and it can be understood if we look at the full cycle of knowledge from a historical perspective, of course freeing ourselves of the epistemological biases that are adopted to justify the prevailing socio-political and economical order. The essence of these biases is the argument that Science is an object of knowledge of a different nature, in the realm of the ratioïd (the "ratioïd" encompasses everything that can be scientifically systematized into laws and precepts). This is particularly strong when we refer to Mathematics. Metaphorically, Mathematics is manichaestic. Its foundations rely on very strict dichotomies.

Knowledge is generated by individuals and by groups, is intellectually and socially organized, and is diffused. The full cycle of the generation, organization and diffusion of knowledge intertwines with needs, myths, metaphors, and interests. The human species, like other animal species, develops strategies of hierarchical power. Intrinsic to hierarchical power is the control of knowledge.

In the discussion about the current state of the World, it is not so important to claim that although the Egyptian, Sumerian and other civilizations were ahead of the Greek, the contribution to build up general mathematical theories was indisputably Greek.[4] It is irrelevant, though largely accepted, that the medieval scholars received Euclid through the Arabs. What is very relevant is the fact that Mathematics as it is recognized today in Academia, developed parallel to Western thought (philosophical, religious, political, economical, artistic and, indeed, every sector of culture). It would be redundant to give examples justifying this assertion. Indeed, Mathematics and Western Civilization belong to each other.

When we question the current social, economical and political order, we are essentially questioning the righteousness of Western Civilization in the face of a real threat to its continuation. How is it possible to avoid ques-

[4] This is the main issue of the polemics about Afrocentrism. See Lefkowitz (1996).

tioning its pillars, Science and Mathematics? How can discussions about these pillars be closed to nonscientists and nonmathematicians? Arguments of authoritative competence lead to intimidation and passionate arguments, as discussed above about the ideological zealots. How can we reach the new by refusing, discouraging, rejecting, or denying the new? Indeed, a subtle instrument of denial is discouragement through intimidation. Language plays an important role is this process, as every schoolteacher knows. Particularly in Mathematics, the use of a formal language, inherent to academic Mathematics, has been a major instrument in deterring critics.

The organization of this language is the realm of epistemology. Epistemologies and histories, the same as norms, differ from group to group, from society to society, and are incorporated in what is called culture. The crux is the dynamic process of encounters of cultures and the resulting mutual expositions, which underlie the construction and reconstruction of knowledge and the maintenance, substitution, dissolution and modification of epistemologies and norms. When authority dominates this process, as it was in the colonial process and equally characterizes conservative schools, the outcome is predictable: contest. The problem thus resides with authority and the denial of participation in the dynamics of this process.

Social and political scientist Marcus G. Raskin and physicist Herbert J. Bernstein, in their analysis of the linkage between the generation of knowledge and political directions, claim that

> science seeks power, separating any specific explanation of natural and social phenomena from meaning without acknowledging human attributes (such as love, happiness, despair, or hatred), the scientific and technological enterprise will cause profound and debilitating human problems. It will mask more than it tells us about the universe and ourselves (op. cit., p. 78).

The Nature of Mathematics

The criticism inherent in reestablishing the lost connection of mathematics, the sciences, technology and human values is causing unavoidable conflicts. This is particularly true with Mathematics, in which the acknowledgement of human attributes is conspicuously absent in its discourse.

This has not been so in the course of history. Mathematics, as with the other sciences, used to be impregnated with religious, as well as social and political considerations. Current Epistemology and History, and above all the educational framework, were constructed to justify the prevailing socio-political and economic order, in which we recognize different "theories of science."

The theories of science largely fail to recognize that generation of knowledge is the result of a complexity of sensorial, intuitive, emotional and rational factors. We are "informed" by these factors and process the information in a way as yet unknown. We need more understanding on how the human mind functions. A holistic approach to knowledge, going from reality to action, owes much to artificial intelligence, biology and sociobiology.[5]

Let us now turn to the question of political power. There are indicators that students spend less time studying or doing homework and that they are bored in class. There is no point in putting the blame on youth, claiming that the current generation is uninterested in learning and intellectually "lost." Perhaps we should look into the blamers. The problem does not reside in youth, but in the older generation, in family, in schools, in the institutions in general. Chiefs of staff are ready to justify sending troops of young age, even teenagers to the battlefield. I know of no decision taken by a young chief of staff to engage in a war and sending the older generation to the battlefield!

As Fred M. Hechinger (1992: 206) puts it,

> The drift toward a society that offers too much to the favored few and too little to the many, inevitably raises question among young people about the *rewards of hard work and integrity* (emphasis added).

The real problems facing education are political, essentially the result of unequal distribution of material and cultural goods, intrinsic to modern economy. There is no need to elaborate on these issues. I suggest a few sources where we find discussion of property, production and global issues in modern society.[6]

Some readers will claim that this has not much to do with the relations among Violence, Mathematics and Mathematics Education. I claim they have everything to do with it. This relationship has been avoided in discussions about the state of the world and Mathematics and Mathematics Education have been absent in the critical views on the main issues. Cultural consumerism practiced both in schools and in Academia, has been efficient in trimming processes and focusing only in results. Mathematics and History of Mathematics are delivered as frozen systems of knowledge, conforming to the *status*

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[5] See Ubiratan D'Ambrosio (1981). I am particularly indebted to Wiener (1948), Maturana and Varela (1987), and Lumsden and Wilson (1981).

[6] For example, see Ubiratan D'Ambrosio (1999). Also interesting is the book by Avishai Margalit (1996). The International Network of Scientists and Engineers for Social Responsibility offers a good electronic forum for discussion of these basic issues.

quo. A frequent inappropriate argument, when one calls for a broader view, is "this belongs to another discipline, not to mathematics classes."

Exceptions are notable. We have to mention the activities of the research group on "Political Dimensions of Mathematics Education/PDME" and also the movements "critical mathematics" and ethomathematics.[7]

There have been few writings about values attached to Mathematics and even less about the moral quality of our action. Search for a correlation between the current state of civilization and mathematics has been uncommon among mathematics educators. Particularly the political component, which was so well studied by Paulo Freire, Michael Apple, Henry Giroux and others with respect to education in general, seems to have drawn little attention of Mathematics Educators.

To a great extent, the polemics around the postmodern discourse of sociologists of science is a reflection of the ideology intrinsic to words. Indeed, language has been the main instrument in denying free inquiry. There is an implicit intimidating instrument in the language of academia and society in general. One must be reminded that of the major confrontations of the sixties, particularly the Civil Rights Movement, the demonstrations against the Vietnam War and the student movements of 1968, probably the first of such contestations of the established order was the Free Speech Movement, initiated by Lenny Bruce.

The human mind is a complex of emotional, intuitive, sensorial, rational perceptions, involving all at the same time. Maybe we have been overemphasizing rational perception and denying, rejecting and repressing the others. Indeed, there is a general feeling that, as a math teacher, one has to teach "serious math" (i.e., objective reason), and to stimulate rational thinking among the students. It is not uncommon to see a child punished for being "too happy" in the classroom. And we all know of teachers saying to a boy, "Stop crying. Men do not cry!" Is it possible to build knowledge dissociating the rational from the sensorial, the intuitive and the emotional?

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[7] Three conferences of the PDME movement were realized: 1995, Bergen; 1993, Cape Town; 1990, London. Proceedings of all three are available. In the Eighth International Congress of Mathematics Education/ICME 8, in Seville, Spain, July 14-21, 1996, the WG 22 chaired by Richard Noss, entitled "Mathematics, education, society, and culture," focused on the political dimensions of Mathematical Education. Frankenstein's work (1989) is representative of this movement. Also see the book by Powell and Frankenstein (1997).

I am reminded of the case of a school teacher who asked children to draw a color picture of a tree seen through the window of a classroom. Jane came up with a tree painted red. The teacher corrected the child, even suggested to the parents that Jane might have a vision problem! A few days later the teacher was sitting in the same place as Jane had been, at the same time of the day, and the Sun was in the same position. The teacher saw the tree as red. Many say that this example is misleading, since it does not deal with objective reason.

I see multidimensionality in building up knowledge as a very important aspect of the History of Mathematics, one which has been practically ignored. And, of course, this is very important in learning.

There has been a resurgence of interest in the intuitive, sensorial (hands-on projects) and affective aspects in Mathematics Education. We must go beyond education and question the discipline itself. What is the role of emotions in Mathematics? When Gustave Flaubert (1987) wrote "Mathematics: the one who dries up the heart," what did he have in mind?

The usual reaction to these comments is: "But this is natural, since Mathematics is the quintessence of rationalism." Indeed. But much of the ongoing polemics relate to the prevailing acceptance of the superiority of rationality over other manifestations of human behavior. This was one of the main concerns of the mathematician-writer Robert Musil in his masterpiece *The Man Without Qualities*. Commenting on scientists and engineers, the main character Ulrich says,

> Why they do seldom talk of anything but their profession? Or if they ever do, why do they do it in a special, stiff, out-of-touch, extraneous manner of speaking that does not go any deeper down, inside, than the epiglots? This is far from being true of all of them, of course, but it is true of a great many....They revealed themselves to be men who were firmly attached to their drawing-boards, who loved their profession and were admirably efficient in it; but to the suggestion that they should apply the audacity of their ideas not to their machines but to themselves they would have reacted much as though they had been asked to use a hammer for the unnatural purpose of murder (1980: 38).

Musil's *oeuvre* anticipates the intellectual framework of Nazi Germany, in which he identifies the incapacity to tolerate pluralism. Indeed, much of the reactions against irrationalism are mixed with a latent emotional incapability to accept the different. The denial of access to knowledge is a strategy for the exclusion of the different.

The threat of extinction is a fact. Paraphrasing Martin Luther King, Jr. in his 1963 speech, the change to nonviolence instead of violence is, indeed, a decision between nonexistence and nonviolence. Do we prefer nonexistence to eradicating violence?

As human beings, we cannot relinquish our duty to cooperate with each other with respect and solidarity, for the preservation of the natural and cultural patrimony. This is the essence of an ethical behavior of respect for the other, who is different in many natural and cultural aspects; solidarity with the other; cooperation with the other. This is a sure road to quality of life and dignity for the entire humankind.

Our main goal is nonkilling. Otherwise, we are on the road to extinction. I am simple in my proposal—we need ethics; and didactic in my style—every individual, whether the sophisticated intellectual or the common man, has a responsibility and should find the means to direct his energies to socially constructive goals.

This is an unusual piece on Mathematics and Mathematics Education, many will say. But if we accept, very clearly and unequivocally, that our professional commitments are subordinated to a more vital commitment to nonviolence, it is absolutely necessary to understand how and why mathematics became such a central instrument, both intellectually and materially, in human knowledge and behavior.

The Essence of Being Human: Survival and Transcendence

Peace, in all its dimensions, depends on an ethical posture not only on human behavior, but also in the production of knowledge. Current systems of knowledge give to the prevailing social, economical and political order a character of normality. Both the religions and the sciences have advanced in a process of dismantling, reassembling and creating systems of knowledge with the undeniable purpose of giving a sense of normality to prevailing human individual and social behavior.

The fundamental problem in this capability is the relation between brain and mind. It is possible to know much about the human body, its anatomy and physiology, to know much about neurons and yet know nothing about why we like or dislike, love or hate. This gives rise to the modern theories of consciousness, which claim to be the last frontier of scientific research.[8]

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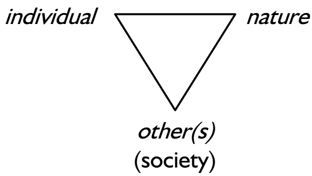
[8] See the important *oeuvre* of Oliver Saks, particularly *An Anthropologist on Mars*. Theories of consciousness also give rise to several academic controversies. See for example the review by David Papineau (1996) of the book by David J. Chalmers, *The Conscious Mind: In Search of a Fundamental Theory*.

Through a sophisticated communication system and other organic specificities, human beings try to probe beyond the span of one's existence, before birth and after death. Here we find the origins of myths, traditions, religions, cults, arts and sciences. Essentially, this is a search for explanations, for understanding, which go together with the search for predictions. One explains in order to anticipate. Thus builds up systems of explanations (beliefs) and of behavior (norms, precepts). These are the common grounds of religions and sciences, until nowadays.

The drive toward survival is intrinsic to life. But the incursion into the mysteries beyond birth and death, which are equivalent to the search for past and future, seem to be typical of the human species. This is transcendence. The symbiotic drives toward survival and transcendence constitute the essence of being human.

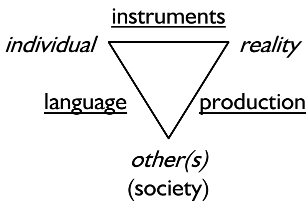
The analysis of this symbiotic drive is focused on three elements, the *individual*, the *other(s)*, organized as a *society*, and *nature*, plus the three relations between them. Metaphorically, complex life may be represented by a triangle, emphasizing that the six elements are in mutual solidarity. The image of a triangle to relate basic components of the model is very convenient. I owe the idea for this triangle (the *primordial triangle*) as well as for the other two (the *enhanced triangle* and the *humanness triangle*) to a paper by Antti Eskola (1989). A mathematical triangle ceases to be by the removal of any of the six elements. The same occurs with the life of an individual. It terminates with the removal of any of the six elements. Life ceases by the suppression of any of the three vertices or the interruption of the relation between them. The following image of the *primordial triangle* is very convenient.



In species with developed neocortex, which we might call superior living species, the pulsion of survival, of the individual and of the species, and gregariousness, are genetically programmed. Reflexes, part of this programming, are usually identified as instinct.

The relations (sides) generate individual and social behavior. The triangle metaphor, meaning the indissolubility of the six elements, is resolved by the principles of physiology and ecology. Basically, the relation between individual and nature is responsible for nurturing, the relation of the individual and the other of opposite sex for mating and continuity of the species. Gregariousness is responsible for individuals organizing themselves in groups and herds, and hierarchies develop, most probably as an evolutionary strategy. The group, thus organized as society, relates to nature aiming at general equilibrium, following basic principles of ecology. Thus, the primordial triangle keeps its integrity. The rupture of each of the six elements eventually causes the extinction of a species.[9] Individual and social behaviors are actions taken "here" and "now."

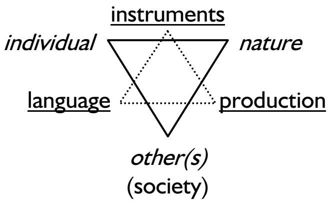
Individuals of the human species, differently than other species with neocortexes, are provided with *will*, that subordinates instinct.[10] Every individual has the ability to generalize and to decide actions that go beyond survival, thus transcending survival. Individuals acquire the sense of before/now/after and here/there. Individual and social behavior transcend here and now. Thanks to will, individuals develop preferences in nurture and in mating. They protect themselves and their kin and they plan ahead and provide. Physiological and ecological principles are not enough. Humans have to go beyond them and the relations (sides) and increment the primordial triangle by creating intermediacies. Between individual and nature, humans create instruments; language intermediates individual and the others; the relation between groups/society and nature is intermediated by production. In the process of recognizing the potential of these intermediacies, humans acquire an enlarged perception of nature. It becomes what is generally understood as *reality*, comprising natural, cultural and social environments. The primordial triangle becomes an *enhanced triangle*:



The three intermediacies are clearly related. Instruments, both material and intellectual, are shared through language and decisive in the production system. The distinguishing feature of language is that it goes beyond mere communication and is responsible for the formation of new concepts. Lan-

[9] For inspiring reflections, see the novel of paleontologist George G. Simpson (1995).
[10] Will is a recurrent theme in philosophy, religion, and neurosciences.

guage becomes essential in forming thought and determining personality features. It is the root of emotions, preferences and wants, which determine the enhanced relations of the individual and the other(s). Language is also essential in the definition and distribution of tasks, necessary for organizing systems of production. Thus, the intermediacies also have a form of solidarity which synthesizes what is called culture. Culture may be thus metaphorically expressed as a triangle, which I call the *humanness triangle*:



Human life is thus synthesized as the pursuit of the satisfaction of the pulsions of survival and transcendence. It is a mistake to claim, as many mathematicians do, that this refers to other forms of knowledge and that Mathematics has little to do with these pursuits. A holistic view of History of Mathematics traces the origins of mathematics in pursuing the satisfaction of these two pulsions.

Engaging in survival, humans develop the means to work with the most immediate environment, which supplies air, water, and food, necessary for nurturing, and with the other of opposite sex, necessary for procreation. These strategies, common to all superior living species, are absolutely necessary for the survival of individuals and of the species. They generate modes of behavior and individual and collective knowledge, including communication, which is a complex of actions, utilizing bodily resources, aiming at influencing the action of others. In the species *homo*, behavior and knowledge include instruments, production and a sophisticated form of communication, which uses language as its means, as well as codes and symbols.

In the search for transcendence, the species *homo* develops the perception of past, present and future and their linkages, the explanation for and creation of myths, and mysteries to explain facts and phenomena encountered in their natural and imaginary environment. These are mentifacts (ideas, values and beliefs of a certain culture) incorporated in the individual memory and retrievable only by the individual who generated them. Material representations of the real, which we generally call artifacts, are organized as language, arts and techniques. Artifacts are observable and interpreted by others. In this process, codes and symbols are created. Shared mentifacts, through artifacts, have been called sociofacts by biologist Julian Sorell Huxley (1887-1975), who also introduced the terms artifacts and mentifacts. Huxley memetic concept of culture contemplates that artefacts, mentifacts and sociofacts have a life of their own, spanning over generations.

Explanations of the origins and the creation of myths and mysteries lead to the will to know the future (divinatory arts). Examples of these arts are astrology, the oracles, logic, the *I Ching*, numerology and the sciences in general, through which we may know what will happen—before it happens! The strategy of divinatory arts is deterministic.

Divinatory arts are based on mathematical concepts and ideas: observing, comparing, classifying, ordering, measuring, quantifying, inferring. Indeed these concepts and ideas are present in all the steps of the search for survival and transcendence.

Every form of knowledge—mathematical artifacts, in the form of practices and tools, and mentifacts, in the forms of aims or objectives, concepts and ideas—is first generated by individuals trying to cope and to deal with the natural and social environment, to resolve situations and problems, and to explain and understand facts and phenomena. These *ad hoc* artifacts and mentifacts are individually organized and are transmitted to other(s) and shared. They attain objectives, they serve, they are useful, they become methods which are shared and acquired by the other(s), by society. They are part of the sociofacts of the group. How are they transmitted and shared? These are the basic questions when we ask for the origins of mathematics. Was the transmission and sharing through observation, mimicry? Eventually, using language. But when? This is historically unknown. We have indications of the emergence of mathematical ideas thanks to artifacts, as will be discussed later in this chapter.

We have no idea when language was used in this socialization. Indeed, the origin of language was an academic "forbidden" theme about one hundred years ago. When language occurred, most probably systems of codes and symbols and specific words were created to design mathematical objects and ideas. This is a major research subject for oral cultures. With the appearance of graphic registry, like cave drawings and bone carving, we have more elements to understand the development of mathematical concepts and ideas. The progress of mathematics through history, in different cultural environments, is a central issue to understand the nature of mathematics. In a recent book, Ladislav Kvasz (2008) discusses the historicity of linguistic tools as a major factor in the development of mathematics.

We may infer that, socially, this factor, which isolates mathematics from consideration of those that are outside the restricted circle of professional mathematicians, is a form of censorship. This kind of obstacle to critical views on the advances of mathematics, of its purpose and appropriation for interest, sometimes unacceptable, was already discussed above. Research that cannot be disclosed is euphemistically identified, in academic circles, as "classified" research, not as "confidential" research. This was clearly illustrated in the movie *A Brilliant Mind* (2001), directed by Ron Howard, a fiction based on the real life of John Nash.

Sharing mathematics advances with the general population requires demystifying mathematics language. In an emblematic phrase, Hilbert (1862-1943), probably the most eminent mathematician of the 20th century, said in the major conference of the 2nd International Congress of Mathematicians:

> An old French mathematician said: A mathematical theory is not to be considered complete until you have made it so clear that you can explain it to the first man whom you meet on the street (1902: 438).

Demystifying mathematical language may open the way to a new form of mathematical education, with more space for critical analyses of mathematical development.

The Threat of Extinction

The only possibility of escaping the threat of extinction of civilization is to attain peace in its broadest sense, in all its dimensions; that is, inner peace, social peace, environmental peace and military peace.

I see peace not as the nonexistence of conflict since, as discussed in the beginning of this paper, every human being experiences different biological, physical, social, psychological, and spiritual needs and wants. Since the individual and the other are different, conflicts are to be expected. The crucial point is to resolve the conflicts without violence. Violence ranges from evident confrontation and aggression and the resource of oppression, but also in more subtle forms of arrogance and bigotry, intolerance and fanaticism.

The only road to peace is through conflict resolution, based on a global understanding of the life phenomenon and intermediacies created by humans, which implies the acknowledgement of differences in the inter- and intracultural dialogue.

A primordial ethics recognizes the mutual essentiality of the three vertices and three sides of the primordial triangle and aims at the preservation of its integrity and survival with dignity. This primordial ethics is synthesized in the box:

- respect for the other with all the differences
  [which are inevitable, since the individual and the other are different];
- solidarity with the other;
- cooperation with the other.

Mathematics in General Education

I repeat what I said above. Many will say that this is an unusual piece on Mathematics and Mathematics Education. Without denying the fundamental importance of nonviolence, they claim that the role of a mathematician and of mathematics educators is to act, seriously and with competence, to attain the specific objectives of the discipline.

But this competence, without a firm ethical commitment, may be directed to reproachable consequences. Particularly, to military innovation. An unsustainable argument of the neutrality of analytical treatment is a resource to support reproachable actions. The seduction of mathematics is responsible for "promoted tricks in technique and the assimilation of dogma at the expense of considered thought" (Hodgson; Screpanti, in Keir, 2006: 22).

This is coherent with what some philosophers of science claim. There is, indeed, a seduction in mathematics. Based on the remarks of Thomas Reissinger, Sanford L. Segal says:

> Mathematical training, however it prepares the faculties for analysis, is not only of no aid in judging historical/political situations, it perhaps inclines toward misjudgment. Furthermore, intellect has no necessary connection to the ability to reason...the ability to reason about ideas depends upon free exchange with others leading to critical examination. The solipsistic aspect of mathematical training and practice does not, however, favor such uses of reason (2003: 13).

This attitude does not differ from what other professionals say of their responsibility *vis-à-vis* their discipline. But if we do accept, very clearly and unequivocally, that our commitment to humankind is much more important than our commitment to the discipline and to its objectives, we cannot passively relinquish our action and give this responsibility to other educational constituencies. Our professional commitments must be subordinated to global ethics, such as the primordial ethics proposed above. Otherwise, it will be impossible to engage in deeper reflection about our roles as mathematicians and mathematics educators.

It is an undeniable right of every human being to share all the cultural and natural goods needed for material survival and intellectual enhancement. This is the essence of the Universal Declaration of Human Rights (1948), to which every nation is committed. The educational strand of this important profession of faith in the future of humankind is the World Declaration on Education for All (1990; see Haggis, Fordham and Windham, eds., 1992), to which 155 countries are committed. Of course, there are many difficulties in implementing the resolutions contained in the document. But as yet this is the best instrument available that may lead to a planetary civilization, with peace and dignity for all humankind.

The crux is to understand how Mathematics and Mathematics Education can be directed as a response to these principles. I see my role as an Educator and as a teacher of my specific discipline, Mathematics, as complementary instruments to move toward my utopia of a world in peace.

In order to make good use of these instruments, I must master them, but I also need to have a critical view of their potentialities and of the risks involved in misusing them. Of course, this has everything to do with ethics.

I believe most mathematicians and mathematics educators share these views. No doubt they are authentically concerned with nonviolence, quality of life and dignity for humankind. But sometimes the relationship between concern and professional practice is not clear. Particularly in Mathematics, there is a general acceptance that if we do Mathematics well, thus instilling attitudes of rigor, precision and correctness in the students' behavior, we are fulfilling our broad responsibilities. Undeniably true. But this is not enough. This must be subordinated to a much broader attitude toward life and toward how mathematics can be used for good or for bad.

The first issue is to understand how Mathematics, as a knowledge system, emerges as a result of the search for survival and transcendence.

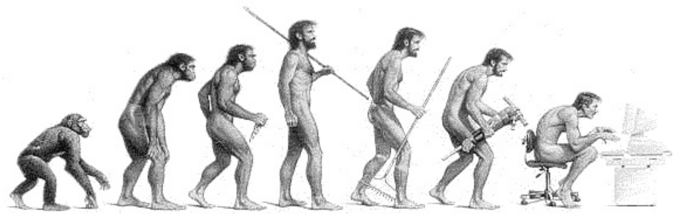
My proposal for achieving this understanding is to discuss the elements of the primordial and enhanced triangles; then to proceed with the knowledge and behaviors acquired in the search for survival and transcendence. Mathematics, as manifest in the techniques of observing, comparing, classifying, ordering, measuring, quantifying, and inferring, is inherent in these searches.

The curriculum I propose below is organized in two steps. The two steps must be integrally covered, but the level of exposition and the required complementary reading is absolutely flexible. I have been developing this curriculum in courses for both future mathematicians and teachers. I frequently have among my students, individuals coming from other specialties. It is the teacher's responsibility to adapt the exposition to the level of the students. It has been possible to develop the curriculum in elementary classes.

The Proposed Curriculum

- **Step 1.** Life is explained as the solidarity of individual, other(s), nature and how they relate. A methodology is to discuss the *primordial triangle* and explain the biological factors keeping its integrity. A first mention of the *primordial ethics* is important in this step
- **Step 2.** In discussing the evolution of the human species, to reach the *enhanced triangle*, we elaborate on individual, other(s), reality, instruments, language and production. Attention should be given to the concept of reality, as enlarged perception of nature, comprising natural, cultural and social environments. A return to the *primordial ethics* is needed.

I have been using an image of the evolution of the species which is very convenient, since it allows for talking about the emergence of the basic ideas of mathematics, particularly observing, comparing, classifying, ordering, measuring, quantifying, inferring. There is much to be explored in this image. Particularly, the autonomy of the individual, which is symbolically represented by its erect posture.



It is very important to pay attention to the various phases of human evolution. *Bipedism*, the first differential from apes, allowed the new species to move using two feet and to discover other things to do with the idle hands (equilibrium is the mathematical manifestation in such a step). Among these discoveries: *stone tools*, for which the mathematical concept of comparison of dimension, rendering the tool appropriate for the designed use, became necessary; and the invention of the *spear*, later developed into arrows and bows, which required the identification of a target in a distant complexity and the development of the mathematical concepts of distance, direction and force (nowadays characterized as a vector, which has magnitude and direction). In this phase, there is good motivation for philosophical reflection about the autonomy of the individual, well exemplified by the possession of a sword in medieval times, and about the generation of a sense of accuracy through mental discipline, as seen in archery. The next phase, leading to history and modern human behavior, is the invention of *agriculture*, and the necessary consequence of coordinated labor, hence hierarchy and power of a different nature (not deriving from physical strength), and of property. It is appropriate, in this phase, to discuss the roots of the capitalist system. The next phase is the development of industry, due to the invention of nonanimal power. A reflection about the mathematics involved in this invention is very appropriate. Again, it is the appropriate moment for socio-political reflections on the condition of the new character of being a worker and the emergence of modern capitalism. The next phase, *humans-with-media*, represents the dominating presence of informatics in all sectors of the modern world.[11]

The figure above reflects a very relevant fact: the ascent of man to individual autonomy, through bipedism, stone tools and culminating with the spear and its derivates, arrow, bow and sword. The symbolic status of possessing a sword in medieval times is most relevant for reflection about autonomy. In a sense, with the emergence of agriculture, individual autonomy was lost. The attachment to the small group of family and tribe was subordinated to an increasingly complex social structure. Agriculture brought the end of nomadism, and brought the concept of property and collective labor and the development of astronomy, a very important moment in the development of mathematics. Industry paved the way to modern capitalism. The age of informatics requires new concepts of privacy. Every one of these phases marked the emergence of new directions for mathematics. Each of these steps demands a deeper discussion of the *primordial ethics*, which is the most important pedagogical practice leading to nonkilling and peace.

Final Remarks

In this curriculum proposal, the right moment for discussion about the search for survival and the search for transcendence is the move from *Step 1*

[11] I use the expression humans-with-media after the important book by Marcelo de Carvalho Borba and Mónica E. Villarreal (2005).

to *Step 2*. This discussion shall emphasize the nature of mathematics as an instrument to deal with the human pulsions of survival and transcendence. This is the moment to elaborate on examples of the relationship between Mathematics and religion, Mathematics and tool making, Mathematics and art.

It is fundamentally important to stress the fact that breaking the primordial triangle implies nonexistence. The enhanced triangle does not change this. The only reason for the enhanced triangle is to make it possible to keep the integrity of the primordial triangle. Again, this is a discussion of how essential behavior is according to primordial ethics for avoiding total destruction of civilization. Paraphrasing Martin Luther King, Jr. it is either adherence to the primordial ethics or nonexistence.

How about a nonkilling mathematics? This is an ill-posed question. Mathematics is in the realm of ideas and, as such, is abstract. For reasons not explained in human nature, its results, methods and language may be appropriated, but does not master, as it was made very explicit by eminent physicist Eugene Wigner in a classic paper:

> Mathematics, or, rather, applied mathematics, is not so much the master of the situation in this function: it is merely serving as a tool…. The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve. We should be grateful for it and hope that it will remain valid in future research and that it will extend, for better or for worse, to our pleasure, even though perhaps also to our bafflement, to wide branches of learning (1960).

Regrettably, Mathematics is practiced and presented both in its pure and applied forms, as a cold and austere sequence of formal steps. In a figurative, somewhat imprecise way, we might say that it emphasizes syntax over semantics. I believe this is responsible for the easy cooptation of mathematicians, as well as of other educated individuals, to put mathematical results, methods and language at the service of material and ideological wants and needs. We might identify this facility to coopt mathematics, a cold and austere sequence of formal steps, as prone to be a killing mathematics. On the contrary, a practice and presentation of mathematics, critically and historically grounded, as proposed in my model of curriculum above, emphasizing semantics over syntax, may resist cooptation and be prone to be used for humanitarian and dignifying purposes. This might be a nonkilling mathematics.

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Nonkilling Science

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What relationships are possible between science and technology, on the one hand, and peace, on the other? In our times neither science nor peace are defined in one single way; any current meaning is questioned and unstable. Owing to this fact, I will offer four meanings of the notions of both science and peace—the dominant ones, the Marxist ones, the religious ones, the nonviolent/nonkilling ones—from a historical perspective. I will then present a way to recognise a nonkilling[1] science in the past development of science and then formally define it together with an alternative way to solve international conflicts. The implications for the relationships between science and ethics are derived.

Military Science and Military Technology

Historically, in order to defend a country from enemy attacks, both science and technology have always been applied for military purposes; that means, in brutal terms, to kill men, provided that they are qualified as enemies.[2] In particular, in the last three centuries improvements in weapons

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[1] One may prefer the word "nonkilling" to the word "nonviolence" because the latter one negates an abstract notion; hence, a priori it is included in the Greek way of arguing through abstract, fixed ideas; that implies the cost of defending the word "nonviolence" from the charge to mean passivity. Instead the word "nonkilling" negates an action which is well identified; hence, it does not leave room for misunderstanding. On the other hand, the word "nonkilling" has the disavantage of referring to a material action, so that it seemingly forgets the psychological violence. However, each of them, because it is a double negated word, is adequate to manifest the alternative way of thinking.

[2] *Bulletin of the Atomic Scientists,* March, 1978, illustrated the historical increase in killing capability by the scientifically improved weapons of all times; killing capability is defined as the number of casualities produced by an hour's use of a weapon against unarmed persons, whose density on the ground is four per square metre: sword 20; crossbow 32; 19th century gun 150; WWI machinegun 13,000; WWI tank 68,000; WWI cannon 470,000; WWII cannon 660,000; WWII tank 2,200,000; WWII bomber 3,000,000; A-bomb of 20 kton 49,000,000; H-bomb of 1 Mton 660,000,000. Of course, these figures represent virtual events because they require such a large and densely grouped popula-

powerfully supported an unceasing arms race, each country thus wanting to achieve the winning strategy for all kinds of war.

In the 1940s the Manhattan project to construct nuclear bombs in the U.S., constituted a milestone in the history of both progress of the arms race and of scientific research; the latter was subsequently organised as an industrial initiative of large groups of scientists financed by funds that only a powerful State could afford. No surprise that the gap between advanced countries and developing countries in scientific research is the greatest (it was, before China started its momentous progress, 97% against 3%); it is similar to the gap in military arsenals only, in particular in nuclear arsenals.

Moreover, military technological progress, and in particular the nuclear arms race, was pursued even by those countries that, being against Western dominant policy, could have reversed this strategic trend; indeed, both Communist and Islamic countries embraced this policy.

In this intellectual framework *peace* is meant in a passive sense, as a trustful delegation by citizens to the experts (and in their turn, to computers!); they, in the name of the best scientific practices, assume the charge of resolving all acute conflicts. In fact, most scientists are working to achieve peace with this attitude.

But as a result of the universal arms race, the level of insecurity of the entire World grew to an unhealthy and absurd level. Through science, which constitutes the best symbol of mankind's highest intelligence with respect to all other species, the human species was able to construct the tools for perpetrating its own destruction. Moreover, the more powerful countries organised their collective defence in such a way that they would be able to launch an attack in a very short span of time, say some minutes, through a highly complex apparatus which for the most part works automatically; the likelihood of a mistake made by this apparatus is very high if we consider the catastrophic consequences of such a mistake. Thus, at the present stage of our development mankind's survival is safeguarded by partially reliable machines!

The story of Einstein constitutes a warning. At the beginning of the 20th century Einstein discovered the formula for producing nuclear energy ($E=mc^2$). Then, in WWII, although he was an anti-militarist and anarchist, he was so frightened by the short-term prospect of Hitler being armed with nuclear bombs launched by means of V-2, that he asked the head of a State (i.e., the U.S.) to build a nuclear bomb; he thought that this was the only

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tion which does not exist over 100 persons. But these figures well represent the growth of the killing power that has been at the disposal of those managing wars.

way to oppose the Nazis' plan to dominate the entire World. But Hitler failed to obtain the nuclear bomb, the U.S. got there first, and then, even though it was not necessary,[3] tested two different bombs on the Japanese people. Of course, Einstein was deeply troubled by the result of his initiative. He was then very active in promoting peace by other means. In particular, he promoted, together with B. Russell, a celebrated Manifesto in which many Nobel prize scientists warned mankind that it faced a dilemma: either to maintain the considerable likelihood of self-destruction, or to promote an unprecedented period of welfare, which could be obtained through the peaceful application of the new scientific theories.[4]

However, his warning was not heeded by dominant World leaders. Nuclear arsenals grew beyond any possible reasonable use for destructive and threatening purposes. After Einstein the link between science and war became so strong that military research prevailed over civil research; for example, in the percentage of U.S. federal funds for research[5] (it was certainly the case in several countries, above all in developed countries). In the 80s U.S. scientific-military research for "star wars" for the first time surpassed both the dimension and the amount of funds of the Manhattan Project; such a gigantic amount of funds polarized the whole of U.S. scientific research. It was unsuccessfully opposed by half of academic scientists, who undersigned a specific declaration of conscientious objection to funds, careers, academic and political power derived from this kind of research.

According to common opinion, unless a new way to defend a country is shown to be viable for the entire population, military violence has to be pursued whatever the costs to other societies, but also whatever social costs are to be supported by its own society.

Peace as a Scientific Solution

What justifies this deeply rooted attitude? Civil society is led to accept the above costs by their enjoyment at the same time of a large number of new commodities produced by Science and Technology for civil welfare.

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[3] It is known that in July 1945 the CIA intercepted and decoded a message from Hirohito to Stalin who was at that time neutral, asking for an honourable peace.

[4] A. Einstein and B. Russell: "Manifesto," 1955; see the site http://www.pugwash.org .

[5] When the East-West struggle was at the height of intensity, an investigation by Woollett (1980), claimed that 48±4% of the scientists in the United States were employed full time in arms production.

Indeed, in the history of Western civilisation the interaction of modern science with technology created a virtuous circle; science produced useful technological applications and at the same time technology produced hints for new theoretical ideas. As a result, science significantly improved, beyond any artisan's imagination, the previously primitive development of technology. And technology achieved such a powerful capacity to transform the World that it now constitutes for each person an exoskeleton (Mumford, 1967), which supports an amazing improvement in his life.

Western historical progress in the last three centuries has been greater than at any time in the history of mankind. It is no surprise if it became the fundamental value of the leading Western societies. Furthermore, such progress was able to involve almost all peoples of the world.

Science and Technology are seen to be intelligent, rational tools that produce the best solutions to both social and individual problems. Scientists volunteered to unravel the knotty problems of the World: hunger (the green revolution, GMOs), energy planning (nuclear power), disease (scientific medicine, genetic modification), etc. Owing to this historical and social capability to transform the entire world rationally, science includes within itself a perspective of peace. Indeed, science is supposed to bring peace in so far as it proposes what is the best solution according to the universal reason: *Calculemus!* (Let us compute!) (Leibniz), and the resolution of a dispute will come without any personal effort. In short, according to this dominant attitude, *peace* can be obtained by supporting science, and scientists are the most effective operators for peace in the world, notwithstanding the enormous destructive power that science was capable of achieving to fight wars.

In the Western world, this pro-science ideology became established because it was accepted by even the strongest political alternative, i.e., the politics of the workers movement. In particular, the Marxist school always supported this kind of science and this kind of progress, wanting to qualify itself as the first political ideology of a scientific nature; it mocked the mythical Luddite worker, who tried to destroy machines in order to save workers' jobs; and moreover it called "renegades" both Duehring and Bogdanov who tried to construct an alternative science of nature.

Some leftist groups criticised science when it became scientism, i.e., an acritical attitude which puts so much trust in science that it attributes to it the power to subjugate politics. The Chinese Cultural Revolution (1958-72) was an attempt to find an alternative to the Western scientific progress that characterized development in the Soviet Union. In Europe the Apollo II mission of U.S. astronauts to the moon gave rise to a heated debate among leftist scientists.

But they all distinguish Science sharply from Technology; according to them, the latter only is influenced by the dominant centres of social power. Hence, *peace* can be obtained by supporting pure science, selecting the positive part of technology and at the same time leading people against the negative part of technology. That means pursuing, beyond demonstrations for peace, a political struggle for not only improving positive technology, but also for conquering, through a revolution (which according to traditional Marxism is a violent one), that new society which alone provides social justice, which then generates both good technology and peace.

Science and Cultural Violence

Putting aside the questions on social misuse of Technology and bad technologies, let us investigate the social role played by Science. We know that in Western civilisation the organisation of Science was such a macho social structure so as to be comparable to nothing less than the institution of the Army. Is the social role played by Science actually a violent one?

Galtung (1990) wisely articulated the notion of violence in the three notions of direct, structural and cultural violence. A culture is violent (at least) when it supports structural violence. By applying these qualifications, it is apparent that scientific culture plays a violent role in present society. If we refer to the most apparent violence, a violence that kills, one has to recall the constantly increasing number of people suffering from hunger (913 million, more than 10% of the World population). Hence, present scientific development proves to be disastrous for the majority of mankind. But people justify the present distressing situation by assuming the prospect of world welfare in the near future, which will be achieved through a certainly beneficent progress for all. Surely, science is one of the main supporters of this justification when it promises for all people significant increases in crop production, new powerful technological tools for agriculture, important improvements in social health and all the other benefits of an advanced social life.

Let us ask: Does Science's violence contingently originate from a number of malevolent people misleading it, or from some negative production structures, or does it even originate from within itself?

In order to answer, let us closely inspect science. Science is a characteristic cultural phenomenon of modern times, unlike any cultural phenomenon of nonwestern societies or even ancient times. Science results from joining experiments with formal (i.e., mathematical) hypotheses. The main characteristic feature of each of its conclusions is to be verified by experiments.

Science is a collective initiative which accumulates objectively verifiable results according to directions of research which explore all sectors of Nature and even the relationship of man with himself. Present Science is a theoretical framework that represents the real world so well that it leaves almost no disagreement between its conclusions and known phenomena. In history, it has become such a great intellectual construction as to constitute a systematic ideology without equal if we look at other systems of thought, which all prove to be weaker, less systematic, and less persuasive in their conclusions. This ideological construction aims to empower mankind to manage Nature in all the specific sectors which it studies.

But it is just this project of empowerment that leads us to suspect a violent role played by science in the history of modern civilisation. As a first approach to a better understanding of the nature of science, let us ask: was the historical development of modern science violent with respect to other cultures?

The birth of science itself had a violent impact on institutional theology, which at that time dominated intellectual life. On that occasion, the Catholic Church won out over the Italian scientist Galileo. But later in Europe modern science had its revenge; it persuaded people that traditional theology was unable to oppose its truths rationally. Then theology was progressively confined to a backward intellectual attitude (Kline, 1953, ch. 17).

Science grew, both in the number of scientists (at present it is carried on by almost a million scientists in the world), in the results (for instance, let us recall that chemistry introduced several tens of millions of new molecules into the environment), and in the fields of human knowledge (from astronomy and mechanics to acoustics, hydraulics, chemistry, geology and psychology), that have been re-formulated on new foundations.

But the expansion of science was so rapid and its impact so great that the single human mind could not grasp it in its entirety. Indeed, modern philosophers have been unable to follow its momentous development. Kant's attempt to reconcile the two ways of conceiving the philosophy of knowledge, i.e., rationalism and empiricism, collapsed when a further development of science—i.e., the birth of the noneuclidean geometries—shook the premises that Kant had maintained to be eternal and ineluctable (in particular, the category of space). Later, most scientists burnt all their bridges with philosophy as well, charging it with being an obstacle to healthy scientific research. Subsequent philosophy was able to suggest merely subjective analyses of science, although science is both a collective initiative and a structural institution of the present society. Three centuries and half after the birth of modern science, present philosophy is unable to define scientific culture.[6]

In short, the birth of science also determined a crisis in philosophy; not only was faith humiliated, but also reason, as it is developed in a philosophical system. In fact, for three centuries there has been no intellectual system that could rival that of science.

Being constituted by universal laws of Nature generated by objective experiments in a collectively verifiable way, over the centuries science claimed to be absolute and not subject to any kind of constraint, and confidently presented itself as an intellectual enterprise devoid of internal conflicts and therefore able to offer an absolutely certain solution to any human conflict. In particular, Newton (1704, 31th Query) wanted to build a new ethics on mechanical laws, encompassing all human behaviour. A century ago, mathematical formalism (Hilbert's programme) claimed that science, when axiomatized, is independent from any link with the outside and is capable of re-stating rigorously the whole of scientific, and even world, culture.

Is Western Progress Truly a Development for Mankind, or Does it do Violence to Spiritual Life?

In the 1930s the sociologist R. K. Merton (1938) characterized the underlying ideology of the West, i.e., Science, as an individualist, Anglo-Saxon and mainly Puritan initiative. The best representative of this kind of scientific initiative was the chemist R. Boyle, owing to his rigorous curriculum of studies, personal goodwill, the spirit of self-denial in devoting himself to discovering nature's secrets, the universalistic passion for mankind's welfare. In short, he interpreted a modern way of living a monk's life, while the architectonic representation of this kind of scientific initiative was constituted by the University colleges, which were built on the model of the old Roman or Gothic convents and moreover were usually named after Saints or even the Holy Trinity.

Most Christian churches shared a favourable attitude toward Science. Moreover, a pro-science ideology of this kind penetrated to the common people and was brought to the Third World by priests and missionaries, who believed that scientific progress would give human dignity to the primitive. In this sense, the expansion of science and technology, which brought with it increased welfare, appeared to naïve persons as a spiritual blessing. Indeed, most people embraced an ideology in which science is a modern salvation

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[6] An exception is the posthumously published analysis by E. Husserl (1970).

not only materially (let us recall epidemics or the work of slaves), but even spiritually in that it eliminates both social and psychic evils.

On the other hand, the powerful Catholic church accused science of being against both religion and spirituality. However, finally, after long, hard struggles, in the 20th century the attitude of the Catholic church became favourable. Without an official document, during the Second Vatican Council the group of "incarnationist" theologians gained ascendancy over the group of "eschatologist" theologians; in other words, in the present attitude of the most authoritative theologians, the will to be involved in even the contradictions of the world prevails over the will to emphasise the separation of spiritual life from the evils of society.

As a consequence, the same theological theory took its place among the other sciences, as a specific science mimicking the techniques and the aims of the sciences that are closest to it. In conclusion, the previously severely condemned Science was accepted as an inevitable reality. What had previously been the enemy, i.e., the Catholic church, was thus conquered by Science. As a consequence, in the last century, society in general formed a favourable conception of science's relationship with spiritual life (even in an atheistic sense).[7] In particular, Catholic theology passed from conceiving peace as a metaphysical "gift from God" to taking up the social slogan: "[scientific] progress is the new name of peace."[8]

Finally, the scientific conception of the world as suggested by Science seemed to be the only one possible. Never in the history of mankind did a cultural phenomenon occur that was so pervasive and so dominant among the people of the world (we find something approaching it in Europe under the Roman Empire and in Christianity in medieval Europe).

A Radical Criticism by the Nonviolent Authoritative Figures of the Dominant Scientific and Technological Progress

What has been said above raises the following question: Is it possible to object to science? The history of the 20th century left two legacies; i.e., a bloody list of scientifically performed slaughters (wars), occurring mainly in Western countries; but also a marvellous achievement, obtained in a non-western country. Gandhi renewed the people's ability to solve conflicts—

[7] See the investigation on 60,000 academic professors reported by R. Stark and F. Roger (2000) and the more recent investigation by E. H. Ecklund (2007).

[8] It is the title of the "Conclusion" of Pope Paul VI: *Populorum progressio*, 1968.

even extreme conflicts such as anti-colonialist struggles and rebellions against dictatorships—with nonkilling means, i.e., without weapons that threaten the survival of the adversary.

This achievement also produced a new way of thinking with respect to the Western tradition, nonviolent political theory.[9] In particular, the nonviolent movement did not share the State's belief that in war ever more colossal carnage represents mankind's progress; this social movement radically opposed wars, the arms race and all social structures supporting them. Owing to the strong link between the arms race and social progress, they concluded that the dominant progress itself had to be contested, including the most monumental product of Western thought over the centuries: Science. The great teachers of nonviolence, Tolstoy, Gandhi and Lanza del Vasto, radically criticized Western science. They shared the thesis that science represents the wrong direction taken by the human soul gone astray. The nonviolent Tolstoy started a radical attack on Western science by asking the question: "Science can give answers to everything but the important question 'What is life for?'" (Tolstoy, 1963 [1882]);[10] that is, Science is separate from our life since it lacks an ethical dimension.

Twenty years later, just a century ago, Gandhi (1909) wrote the "redbook" of the Indian revolution: *Hind Swaraj*.[11] In it Gandhi radically questioned, from the viewpoint of ethics and nonviolence, one after the other, all the areas of Western progress. He also suggested how to rebuild them on a clear ethical basis, at the cost of being accused of a backward attitude. He also criticised Western science.[12]

Gandhi's criticisms mentioned above have been considered too crude even by the politicians who followed him. But fifty years later, his one Western disciple, Lanza del Vasto, improved on them. He based them upon two sacred texts of the Western tradition.

He interpreted the Original Sin (Genesis 3) as an inversion of human knowledge, from the loving contemplation of the World to the knowledge-calculation

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[9] Beyond the several books by authoritative nonviolent thinkers, see Drago (2007).

[10] Weber (1919) reiterates this question as one of the most important ones.

[11] Indian tradition qualifies this epoch as the *Kali Yuga*, the Dark Age.

[12] Anthologies of Gandhi's writings (an endless number of short articles comprising more than a hundred volumes) usually miss these criticisms. In Gandhi (1986), sections 108 and 110 quoted the more mild ones.

of good and evil used for utilitarian purposes.[13] This exploitative attitude regards not only nature but also people. Hence, this original sin is not is not coming to us from ancient times, but is inherent in the constitution of every society; it is essentially a structural sin. Within social relationships it grows by exploiting formalities to cover up selfishness. Among them, the most formal intellectual activity, i.e., the making of laws, which actually formalises pyramidal social power in a society, and even more so Science, whose aim is formally to exploit nature for the benefit of all, hides any number of malicious political aims.

By hiding the attitude of domination of the few over the many, the above *formal* institutions may grow until they completely dominate the people, as an impersonal dictatorship. According to Lanza del Vasto, this extreme social situation is described by Apocalypse 13, through a Beast rising from the sea and dominating the world. He interpreted it as modern Science, because "The irreparable lack of modern science is that it lacks someone who knows it entirely" (Vasto, 1959: 240); that means that at present we are subordinated to the super-human project constituted by scientific progress. Then Apocalypse 13 describes a Beast rising from the earth, whose authority depends on the power of the former Beast. Lanza del Vasto interpreted it as the Machine, or the State-Machine, which, by dispensing numerous facilities and conveniences, leads to a false kind of development, where even the wisest seeks personal profit rather than cooperative fairness. Social life becomes based on such a degree of alienation as to become entirely subjugated by the two Beasts:

> And he shall make all, both little and great, rich and poor, freemen and bondmen, to have a character in their right hand or on their foreheads: And that no man might buy or sell, but he that hath the character, or the name of the beast, or the number of his name.

It is easy to see in this description the dictatorships that infested advanced European countries some decades ago. Thus, modern civilisation, by

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[13] Vasto (1959). Summarised in three lectures in English which he gave in Gujarat Vidyapith in 1977; see http://www.wikilivres.info/wiki/Pilgrimage_to_Non-violence. A similar interpretation of original sin has been already suggested by Toynbee (1948). Incidentally, notice the following statement by Toynbee on religious violence: "A church is in danger of lapsing into this idolatry insofar as she lapses into believing herself to be, not merely a depository of truth, but the sole depository of the whole truth in a complete and definite revelation." By merely replacing the term "church," this statement may be applied to Science.

relying upon the worldwide expansion of Western science, is seen by Lanza del Vasto as the greatest renewal of Original Sin.[14]

At present this negative attitude toward modern science goes against the present attitudes of Christian churches. It is on this issue that there is greatest divergence between the nonviolent attitude and the attitude of Western Churches, otherwise very sympathetic to nonviolence. But at present this critical vision of Science is shared, at least in part, by some political movements, e.g., the radical ecological movement.

According to the above nonviolent teachers, the meaning of *peace* is the opposite to that attributed to peace by the traditional scientific vision for which its meaning is abstracted from the person's life; the former, by trying to solve conflicts through interpersonal relationships, relies heavily on the personal witness of the kind of life one chooses. Moreover, peace is understood not just at an individual level; a new ethics is actively sought at the political level of society as a whole. Let us recall that Gandhi's life united Indian and Western culture through the notion of "law"; which in the West is juridical law (of which Gandhi, as a lawyer, was a representative) and in the East is inner law ("the little inner voice"). Therefore, in the wide arena of all social relationships peace is achieved by promoting a new kind of social ethics which relies on co-responsibility,[15] egalitarianism, sharing, justice, and community. In short, an ethics relying on trust in man and therefore anti-Machiavellian.

Any Conflict within Science?

But, if the nonviolent position of the great teachers is correct, i.e., that science represents the breeding ground of present cultural violence, then should we reject Western science?

Indeed, the above criticisms of science come from outside science. They may be the result of pre-conceptions, insistently maintained by some who

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[14] In the history of interpretations of Apocalypse 13, the one above is the first interpretation of a structural kind, i.e., it sees the actors in terms of social structures, instead of some individuals or even abstract ideas. As a consequence, it involves a conversion not only at the personal, but also at the collective level. The foundation of a communitarian life is an instance of an alternative society [Lanza del Vasto founded, first in France (1948) and then in some other countries, the Ark communities, which are similar to Gandhian communities] and struggle to change both evil institutions and negative society.

[15] Some decades later, H. Jonas (1979) started a renewal of social ethics by supporting the view that we have to be responsible with respect to both mankind's survival and the welfare of future generations.

are nostalgic for the past, as well as by those resistant to change.[16] However, I have taken these criticisms seriously, especially those of Lanza del Vasto, and I have devoted thirty years of my scientific life trying to clarify the problem (Drago, 1978, 1986). I asked: Does an alternative science exist? Does a nonkilling, nonviolent science exist? First of all, is there a conflict between two ways of producing science?

Let us start to explore science on the basis of the above questions avoiding what cannot be fully grasped by laymen, i.e., the technicalities or a philosophical debate. We will look at the historical development of the relationship between science and conflict; and then at the conflicts within science.

Two historians of science introduced the subject of the conflict into their illustrations of past science. Fifty years ago, A. Koyré (1957) cleverly interpreted the birth of modern science as determined by the use of the notion of infinity. Remarkably, at that time some scientists (Huygens, Descartes, etc.) supported *potential infinity* (whose best instance is a counting of natural numbers, i.e., an unlimited process which lacks a final number); whereas other scientists (Newton) supported *actual infinity* (whose two best instances are the final end, i.e., the point at infinity, of a straight line and the infinitesimal, which is defined as a number which is less than all real numbers).[17] Hence, Koyré highlighted a basic conflict at the birth of modern science. (Notice that in this dispute it was Newton who finally won. But I remark that a century and half later, an entire physical theory, thermodynamics, was born by making use of a mathematics that lacked actual infinity.)

The historian T. S. Kuhn (1969) also suggested a conflictual vision of the history of science, which in his case concerned the development of classical physics as a whole. He thought that science proceeded by constantly applying a paradigm that is shared by the scientists that make up the scientific community. But it may occur that a specific case-study (such as the black-body theory in theoretical physics at the end of the 19th century) halts the successful appli-

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[16] For instance, there are several celebrated books on the relationship between modern science and Eastern philosophies; e.g. Capra (1976), Zukov (1983). But they compare intuitively scientific notions with those of Eastern philosophies, without examining the formal notions of science.

[17] This shows that science includes a philosophy. Already a century ago one scholar concluded his investigation into the foundations of science by the following insight: "Metaphysics they [the scientists] tended more and more to avoid, so far as they could avoid it; so far as not, it became an instrument for their further mathematical conquest of the world" (Burtt, 1924: 303).

cations of this paradigm. Such a case-study constitutes a theoretical anomaly, which brings about a scientific revolution (in the above case-study, the quanta revolution), leading to the replacement, through a Gestalt phenomenon in the minds of the entire scientific community, by a new paradigm (the corpuscle-wave complementarity) of the previous paradigm (the continuous vision of reality). Owing to the Gestalt change, the new paradigm proves to be incommensurable with the previous one, with the risk of untranslatability, and even incommunicability, between the two paradigms. In other terms, according to Kuhn, science suffers conflicts between successive paradigms.

However, both Koyré and Kuhn made use of, rather the basic notions of the science itself, some philosophical notions; respectively, infinity; and paradigm, anomaly, revolutions. Hence, their analyses are merely philosophical analyses which are cleverly supported by suggestive historical cases; but they did not achieve scientific proof of the validity of their interpretations.

A more accurate inspection of past science reveals that some scientists also introduced conflicts within science. Already at the end of the 19th century, Haeckel proposed a new science, i.e., ecology. It originated from a new, global scientific vision of reality (*oikos* = home), as opposed to the local, analytic vision of dominant science. It was moreover based on the notion of cycle rather than on either ideal notions (absolute space in Newtonian mechanics) or functional relationships (the field in electromagnetism). Haeckel's theory was almost ignored by the scientific community. But after a century, it was realised that the various kinds of pollution, the result of ecological ignorance of cycles in nature, constituted a threat to human life on the planet. The academic world reluctantly had to inaugurate a specific University curriculum on ecology; however, it conceived the curriculum as the study of a series of analytical techniques, rather than a global scientific method.

More recently, I. Prigogine (1984) charged Newtonian mechanics with having led to the catastrophic exploitation of Nature; in order to establish "a new Alliance" with nature, it is necessary for the first time to understand life scientifically. To this end, he proposed thermodynamics as the more appropriate theory to start to establish a new, harmonious alliance between mankind and Nature. Such a proposal added the mathematical theory of chaos, which claimed to go beyond the deterministic conception of Newtonian mechanics and hence radically changed the previous scientific conception of the world. In addition to the theory of chaos, Prigogine, together with several other scientists, proposed the mathematical theory of complexity as the new direction of scientific research. In other words, through a new scientific attitude he supported a program of scientific research which would achieve a new kind of scientific development.

Hence, ecology, Prigogine's program and complexity theory propose for the future a vision of scientific progress that will renew that derived from mechanistic science. But they do not clarify the nature of their opposition to traditional science, i.e., whether it is merely cultural and therefore collateral or complementary to traditional science; or whether they are proposing a truly alternative science.

Although they are unable to recognise at what point in the foundations of science there exists a conflict and what its nature is, all the above scientific proposals suggest some philosophical distinctions, e.g., analytical and global, deterministic or chaotic, simple and complex, etc.

Let us now consider what the above implies for the notion of *peace*. Both scientific programs, Haeckel's and Prigogine's, involving respect for life and hence outlawing the very ideas of war, enemy and destructive solutions to conflicts, suggest an active process for achieving peace. They therefore imply positive peace, rather than the passive peace suggested by the dominant science.

This radical change in the meaning of peace is in agreement with the nonviolent meaning of peace. Such an agreement encourages us to proceed in search of a nonviolent, nonkilling science. However, nonviolence adds to the previous meaning by specifying the global method by which one searches positively for peace; nonviolence suggests that in the process of achieving peace as an alternative way to war, it is necessary to focus attention not only on the aim, however positive it may be, but above all on the tools employed, which have to be nonviolent if they are to be adequate to achieve the positive aim.

The Birth of Conflict and Pluralism in Science during the French Revolution

A more accurate analysis of Kuhn's history of science does not support one crucial point of his interpretation, i.e., the birth of classical chemistry, which was not determined by any "supra-mechanical aspect";[18] rather, it is

[18] Kuhn (1969, ch. 9): "The large body of eighteenth-century literature on chemical affinities and replacement series also derives from this supra-mechanical aspect of Newtonianism. Chemists who believed in these differential attractions between the various chemical species set up previously unimagined experiments and searched for new sorts of reactions. Without the data and the chemical concepts developed in that process, the later work of Lavoisier and, more particularly, of Dalton would be incomprehensible [this footnote refers to the historian Metzger]. Changes in the standards governing

well known that it was the result of a cultural battle against the Newtonian tradition of interpreting chemical affinity through gravitational force. Moreover, a similar analysis does not support Prigogine's thesis that the birth of thermodynamics was no more than "an abortion" of the alternative that he is searching. Rather, past historians have been unable to understand the genius of the founder, Sadi Carnot;[19] moreover, one has to remark that thermodynamics seems at first glance to be an alternative theory to Newtonian science because it was formalised without actual infinity and all its variables are global in nature. A more accurate historical appraisal is therefore necessary of the origins of these two scientific theories, and, more in general, of the corresponding period of the history of science.

The French Revolution wanted to reform Newton's science, accusing it of being mythical in nature (Gillispie, 1962). Lavoisier is known for having done so in chemistry by rejecting Newton's notion of affinity as gravitational force. He intentionally published his main book in 1789, the same year as the French revolution; in the introduction he wrote that he sought to bring about a "scientific revolution." Moreover, during this period all scientific theories were founded anew: geometry (Monge, L. Carnot, Poncelet), infinitesimal calculus (L. Carnot, Lagrange), mathematized mechanics (L. Carnot, Lagrange, Navier, Poisson) and, in addition, thermodynamics theory began (S. Carnot) [Drago, 1982, 1990, 1991a,b, 1997, 2004]. Historians evaluate the revolution in geometry, i.e., Lobachevsky's invention of noneuclidean geometry in the remote Kazan University, as a long-term consequence of the French revolution.[20]

A leading figure of this renewal of science was L. Carnot. In opposition to celestial mechanics (the best application of Newton's mechanics, which relies upon the metaphysical notions of absolute space and absolute time), he founded terrestrial mechanics (dealing with the impacts of bodies; and more precisely, the mechanics of machines; notice that each of them is a

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permissible problems, concepts, and explanations can transform a science." Here it is apparent that Kuhn wants to attribute Lavoisier's foundation of classical chemistry to a "supra-mechanical aspect of Newtonianism." Hence, he does not see any alternative to Newton's mechanics. Otherwise, his conception of the scientific conflict as a conflict between a paradigm and its successive paradigm only (not among contemporary paradigms), produced a paradoxical result; classical chemistry was to be considered the new paradigm, succeeding in subsequent theoretical physics to Newtonian paradigm.

[19] Fox (1988) offers a final appraisal of the research carried out according to the dominant attitude among the historians of this case-study, i.e., interpreting S. Carnot's exceptional theoretical novelties by means of historical factors of a technological nature.

[20] Yushkevitch (1989); Drago (1995); Cicenia, Drago (1995).

complex aggregate of bodies, which was considered by L. Carnot globally). He founded the theory on the practical concept of work and not on the metaphysical one of force-cause. Moreover, he re-formulated both of the mathematical theories of his times, i.e., geometry and infinitesimal calculus, in an alternative way. Furthermore, he suggested to his son Sadi the key ideas that gave rise to thermodynamics, whose theoretical structure is very different from that of Newton's theory.[21]

L. Carnot's main scientific achievement was to suggest an alternative to the dominant organization of a scientific theory. Instead of the pyramidal organization (which we find theorised by Aristotle and then instantiated by both Euclid and Newton; at the top it puts "evident" principles, from which all laws are deductively drawn; we will call it AO), L. Carnot's new kind of organisation (we will call it PO) is centered on a general problem (in mechanics: that of finding the invariant quantities during a phenomenon of an impact), *to which the development of the theory finds a general solution*.[22]

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[21] L. Carnot (1783, 1803, 1813, 1803). A first comprehensive study of Carnot's work is C. C. Gillispie (1971). About the scientific relationship between the two Carnots see ch. III D. Notice that L. Carnot's theory (which tackles an extremely complex situation, constituted by a machine composed of an unlimited number of levers, wheels and impacting parts), and even more so S. Carnot's theory (which tackles the complexity of a gas, where there is a jumble of millions of billions of billions of molecules mutually impacting), show that a complex situation may be easily solved in scientific terms when the appropriate theoretical parameters are recognised. In fact, the aforesaid theories have abandoned the analytical attitude of examining the single parts, or molecules (a typical feature of Newtonian mechanistic physics) composing a system, and instead proceed to assess the situation using global parameters such as energy, volume, temperature and gas pressure. These theories were the beginning of a conflict with Newtonian theory, hence a conflict between the various physical theories. Notice that nothing is more complex than a conflict, because it is always changeable and unforeseeable in all its implications. Hence, the birth of complexity theory, underlining the complex phenomena which have to be formalised by a non-local, non-analytical attitude, may be seen as the first approach to recognise conflicts between scientific theories. In my opinion, such complexity is more relevant than complexity in reality. The weakness of present complexity theory also appears when one considers that it does not make a clear choice between the analytical and the global attitude.

[22] See the lucid presentation of the alternative in the organization of a scientific theory, although he qualified as "empirical" the OP: L. Carnot (1783: 101-103; 1803: xii-xix); Drago (2004). Independently, both H. Poincaré and A. Einstein arrived at the same result: H. Poincaré (1903, ch. "Optique et Electricité"; 1905, ch. 7); Einstein (1957); Miller (1981: 123-142).

Also S. Carnot founded thermodynamics by posing a central problem (maximum efficiency in energy transformations); and by then finding a new method (Carnot cycles) that solves this problem.

The discovery of two ways of organizing a scientific theory suggested to L. Carnot a pluralistic attitude toward the foundations of science. He clarified it in infinitesimal analysis. In this theory he accepted and supported all the various foundations of analysis on the basis of a pluralistic attitude. His book received wide popular acclaim, but was then dismissed by the "war-like" attitude of the academic world of the subsequent age, according to which in any scientific theory proposed—if only for didactic reasons—there was only one foundation which cancelled out all others.

Soon after the French revolution in Kazan, a remote town in Russia, Lobachevsky (who had studied French books) was able to propose a new kind of geometry. He did not just change a single postulate (the fifth), but posed the problem of how many parallel lines there are and put forward an original method to solve it. He thus changed the entire theoretical framework of Euclidean geometry.[23] A few decades after the failure of the French Revolution, the labour movement (unfortunately ignoring the new scientific theories) wanted to start an alternative theory in social sciences. Marx' theory tackled the central problem of how to overcome capitalism in the history of mankind; first he studied the relationships between factory owner and workers, rather than that between buying and selling in the market; then through his studies he sought a new political method, based on scientific principles, for bringing about the social revolution.

I would also point out that the both Carnots and Lobachevsky's theories are alternative not only in their organization, but also in their use of mathematics. Instead of Newton's (metaphysical) infinitesimal calculus, which includes actual infinity (or its inverse, the infinitesimal *dx*), they make use of a mathematics that is appropriate for operative calculations; i.e., it relies on potential infinity only. We might conclude that the French revolution gave rise historically to pluralism in scientific theories.

What was the relationship in this period between science and conflict (war)? Over the centuries, science has always been exploited for war purposes.[24] However, an alternative attitude came into being during the French revolution. The military devoted itself to improving civil society. In

[23] Drago (1995); Cicenia, Drago (1995); Drago, Perno (2004); Bazhanov, Drago (sub.).

[24] For a general view, see Nef (1952). A relevant exception was C. Huygens who wanted to exploit cannon powder to build an engine.

other words, at that time there was a process of conversion of those working in the military to civil purposes. Most of the new scientific theories of the French revolution were the work of military scientists: Monge, L. Carnot, Poncelet, Navier, Poisson; in particular thermodynamics was born almost entirely when former soldier S. Carnot turned his attention from cannons, mythologised as having almost unlimited power, to civil machines, which he studied from the point of view of maximizing their efficiency (Salio, 1982).

On the other hand, during the French revolution civil society wanted to apply human reason to social life as a whole, in particular to creating an alternative State to the old absolute, metaphysical State (recall the blue blood of the kings!).

In fact, the French revolution succeeded (notice, before Napoleon) in reforming the State's military sector. It turned the mythical military structure of the aristocracy, which was aimed at the kingdom's expansion, into an institution that was an expression of the people's will simply to defend civil society. Indeed in 1793, when the European monarchies united against revolutionary France, a military structure was rapidly re-built by means of the first great "levée en masse." It was launched by the supreme head of the French army, Lazare Carnot. With a military background, he had theorized before 1789 the new strategic theory of total (popular) defence (as opposed to the ideology of "total war" that had just come into being). In 1793 he successfully applied this strategy to defending democracy. The French people, although weaker in destructive weapons, achieved "Victoire."

Exactly two centuries later, in 1989 the peoples who freed themselves from the dictatorships of Eastern Europe reiterated this policy of people's defence and defeated a super-power which was ready for the greatest destructive confrontation in mankind's history. The French Revolution had therefore anticipated the only possible alternative we have today to the mythical and disastrous arms race, i.e., collective defence only; and moreover a defence that is not entrusted to the mythical destructive power of an enormous military arsenal, but to the solidarity of a populace wanting to protect both itself and its democratic institutions. Hence, in national defence there exists an historical tradition which constitutes an alternative to merely destructive defence, of which nuclear defence is an example.

More in general, in the history of the relationship between science and war, the link between the dominant science and the development of ever more destructive weapons is clear. However, the French revolution established a new, alternative link; even extreme conflicts are solved in the wisest way, as it was first exemplified by Gandhi and in the 20th century by many other peoples. What is extraordinary in the French revolution is that the new notion of defence was developed by individuals from the military.

But in the following period, the policy of the Restoration was to present science as it had been before the French revolution, i.e., without internal conflicts, and to outlaw many scientific theories. After 1850, when the bourgeoisie took social power, most of them were rehabilitated; but some of the previous theories have never been accepted,[25] in particular, Marx's theory, but also some "revolutionary" scientific theories (e.g., those of L. Carnot). On the other hand, Lavoisier's chemical theory survived despite academic opposition, because it was supported by chemists and chemical engineers, who were indispensable to contemporary society.[26]

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[25] Indeed, the Restoration institutionalized academic science according to a number of authoritarian constraints: (1) the setting up of scientific academies with rigid professional roles; 2) "rigorous" procedures to communicate and accept scientific results; (3) embedding science in a sophisticated (mathematical) language which acted as a barrier against those who wished to discuss fundamental problems; (4) splitting up scientific work in several fields, that are sharply separated one from another (e.g., economics from physics, in particular thermodynamics; mathematics from computing machines, etc.); and (5) maintaining scientificity as the final criterion also for solving social issues; that is, a monolithic science set above all other social values. See Ben-David (1974).

[26] Three decades ago an alternative within scientific theories was suggested by an important social problem, i.e, the energy crisis, which recalled the scientific alternative of one century and a half earlier. Due to the oil crisis of 1973, the Western world discovered that as a society it had never taken into account energy consumption and energy waste. In reaction, the dominant scientific attitude foresaw the same rate of progress as in previous years, i.e., an exponential growth of energy consumption; as a consequence, society had to produce a huge amount of energy (mainly electrical). It seemed that nuclear power, developed thanks to most advanced modern scientific theory, i.e. nuclear physics, could guarantee such levels of production. It was presented as the only viable solution and its opponents were not credited with rationality. Yet surprisingly, the second principle of the older theory of thermodynamics contradicted the development of nuclear power. The American Physical Society discovered that, strangely enough, for over one hundred and fifty years Western society had not applied the specific scientific theory of energy, i.e., thermodynamics, whose central idea is that in any energy transformation the optimum yield is given by a S. Carnot cycle, whose efficiency depends on the difference between the temperatures of the heat source and the temperature of the final use. Hence, it would be wise to choose that energy source whose temperature is as close as possible to the temperature of the final use. By disregarding this principle, the present social organization systematically leads to an enormous waste of energy (APS Study Group, 1976). The alternative energy planning chooses low temperature and renewable sources of energy, because

Formally Qualifying the Conflicts within Science

We have considered some conflicts concerning the history and the philosophy of science. There have even more decisive conflicts within science after an acute crisis in the first years of the 20th century, through studies investigating the internal structure of science; that is, the foundations of both mathematics and logic.

The study of the foundations of mathematics recognised an essential conflict between two kinds of mathematics; i.e., the dominant mathematics that is taught in scientific Faculties and includes actual infinity (which we will call AI), and the mathematics that makes use of potential infinity only (we will call it PI). The latter mathematics is closely approximated by the mathematics that represents the working of the computer. Four decades ago this conflict was formally founded.[27]

As evidence for the idealistic nature of the dominant mathematics, it should be noted that past mathematics, being metaphysical in nature owing to the use of actual infinity in several specific notions, such as infinitesimals, never dealt with conflicts before World War I. Two centuries and a half after the birth of infinitesimal analysis, some scientists succeeded in doing so when they discovered that two coupled difference or differential equations describe phenomena of mutual competition, including the arms race. Euler could have developed this theory two centuries before, if he had not been prejudiced by the idealistic nature of the dominant mathematics. Between the two World Wars, game theory was born. It analyses in detail the aspects of a conflict by means of few integer numbers. The mathematical technique is so elementary

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they are more suited to the final use of energy at the local level. Hence, the question: "How much energy?" was followed by the question: "What kind of energy?" The debate made it clear that there exists a distinction between two radically different ways of producing energy for a society (U.S. Senate, 1975; Lovins, 1977). One may trace back the internal conflict within technology to S. Carnot who began his booklet on thermodynamics discussing energy planning for a society; moreover, he warned of energy crises and foresaw the great change in future society brought about by the widespread use of heat engines. Even more importantly, he suggested the criteria for achieving the greatest efficiency in energy transformations.

[27] Bishop (1967). Notice that the dominant mathematics, the so-called "rigorous" mathematics which was developed by both Cauchy and Weierstrass in the 19th century, includes actual infinity even in the basic notion of limit. See Kogbetlianz (1968, App. 2).

that even Archimedes or Galileo had the technical capabilities to develop it.[28]

As an important consequence, game theory inaugurated a new mathematical relationship with reality which is alternative to the relationship established by Newton's theoretical physics. Instead of the metaphysical mathematics of the infinitesimals, it makes use of the more elementary theory of constructive mathematics, i.e., the theory of integer numbers.

It should be noted that almost in the same period of the birth of game theory, theoretical physics too had to admit that all reality is constituted, in a "complementary" way to waves, by quanta which require the mathematics of integer numbers. And soon after game theory, theoretical biology also came about in association with discrete mathematics (e.g., a neuron as a two-state switch, the constitution of DNA by an integer number of bases, etc.) all outside continuous mathematics and even more outside the AI. Since that time a conflict was apparent between the new scientific theories and traditional science linked to the idealised mathematical continuum (including AI; for instance, the notion of infinitesimals).

In the above we have already seen that this novelty was anticipated by science during the French revolution. Chemistry was born from the mathematics of integer numbers; and more in general both L. Carnot's mechanics and S. Carnot's thermodynamics made use of the mathematics of the PI only.

At the end of the 19th century there was confidence that logic, having been mathematicized, had achieved an absolute nature. Nevertheless, at the beginning of the 20th century a conflict also arose in mathematical logic; in addition to classical logic, several kinds of different mathematical logics were discovered. In particular, it was discovered that it is not the law of the excluded middle (either "A is true" or "not-A is true"), but the law of double negation ("Two negatives affirm"). This distinction constitutes the borderline between classical logic and almost all kinds of nonclassical logic; in the latter kinds of logic two negations do not affirm (for example: "Absolved owing to the *lack* of evidence of *guilt*" does not mean that the accused person is clean-handed, but that the court had insufficient evidence to establish whether he was guilty or not). Hence, mathematical logic is split into (at least) two incompatible branches.[29]

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[28] Newmann, ed. (1956); Rapoport (1964). A celebrated application of Rapoport cleverly describes the arms race, carried on by the two superpowers, through the game of prisoner's dilemma.

[29] Dummett (1977); Prawitz, Melmnaas (1968). In the following I emphasize the negative words in a doubly negated statement in order to show its nature.

Again one can trace back the use of nonclassical logic to some centuries before, in particular to some scientists of the period of the French revolution. In their original scientific work one finds several sentences which are doubly negated statements of nonclassical logic: "We call element what we *could not* yet *decompose*" (Lavoisier); "A *never* ending motion is *impossible*" (L. Carnot and S. Carnot); "This hypothesis [of two parallel lines to a given one] does *not* lead to any *contradiction*" (Lobachevsky); "These two postulates [constancy of the light speed and relativity] are *only apparently irreconcilable*" (Einstein); "One *cannot* simultaneously measure an object's position and speed with *absolute* [= *not* relative] accuracy" (Heisenberg). Each of them play a fundamental role in the respective scientific theory.

It is precisely on this logical point that the enormous experience of Freud, who founded the theory of inner conflicts, was based. He explained his method in a paper of a few pages (1925). He points out that the analyst asks the patient to speak freely about say, what he dreamt. The patient tells a dream; he met his mother; but a dispute arose and he, in a fit of rage, nearly killed her; but then he urges: "I did *not* want to kill her." The analyst must notice this negation and, in turn, has to add one more negation: "It is *not* true that the patient did *not* want to kill his mother."

The doubly negated sentence provides the clue to recognising the trauma that the patient has repressed in the past (i.e., denied in his inner self) which, however, emerges again and again. This enables the analyst to recognise the repressed part of the patient and hence to start the healing process.[30] Let us remark that Freud's whole theory is in agreement with the PO theory; he poses the problem of the patient's healing, then solves it through the invention of a new method, which interprets the dialogue inductively through doubly negated sentences constructed upon the patient's negated sentences.

Nonclassical logic also plays a fundamental role in conflict resolution when it is considered in general terms. Let us recall that the great discovery of the 20th century was the nonviolent method. In fact, the very term nonviolence (as nonkilling) is a double negation (killing being a *negation* of life). Notice that it does not have a positive equivalent (notwithstanding Gandhi's efforts to substitute for it the affirmative word "satyagraha"); thus, the two negations do not affirm. On the contrary, the military way of theorising the resolution of a conflict in the barracks makes use of classical logic, enforcing absolute certainties:

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[30] It is also well known that Marx, the theoretician of social conflicts, tried, by turning upside down Hegel's metaphysical dialectics, to obtain a new logical way of arguing; but unsuccessfully, although he made use of many double negations.

"The *enemy* of my *enemy* is my friend" where the two negations affirm; and also of the equivalent logical law of the excluded middle: "Either friend or foe," "Either patriot or stranger," "Either obedience or disobedience," etc.

Hence, unlike the classical logic of the military, the word "nonviolence" introduces an entirely new way of reasoning with respect to the dominant one. This fact is also apparent in logical terms; indeed, classical logic guarantees rigorous deductions, whereas nonclassical logic is the basis of inductive argument.

Since both logic and mathematics are the foundations of all branches of science, from the above two kinds of conflicts it follows that there is a fundamental division within science as a whole, giving rise to intellectual conflict.[31]

Such a division within both logic and mathematics generates divisions within each scientific theory through both the plurality of its formulations and the radical variations in meanings of its basic notions when changing the formulation of the theory and even more when changing the theory itself. For instance in geometry, a straight line conceived of either as an infinitely prolonged segment (Euclid and Lobachevsky) or as possessing two end points (Hilbert); in theoretical physics, either absolute (in Newton's mechanics) space or relative space (in L. Carnot's mechanics, and even more in special relativity); continuous time and time as before and after (in the same two different formulations) and even space-time (in special relativity for which, moreover, mass fuses with energy); the classical notions of both wave and corpuscle playing complementary roles in quantum mechanics, etc.

Notice that the two different logical worlds are mutually incompatible in their basic tenets. But, each doubly negated sentence is an open sentence; hence, nonclassical logic is not exclusive in nature (as is classical logic; let us recall military logic). It allows mutual dialogue and coexistence; that is, it introduces a fundamental pluralism.

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[31] We have already remarked that in the energy debate, involving essentially scientific principles, there were two different and irreconcilable positions, of equal scientific validity; i.e., nuclear energy planning and soft-energy planning. In fact, a similar division occurred in each applied scientific sector. A similar division is clear in agriculture, between chemical-industrial agriculture on the one hand, and organic, or biodynamic, or permacultural agriculture, etc. on the other. A similar division also exists in the health sector, between the dominant bio-chemical medicine and homeopathy, or acupuncture, or herbal medicine, etc. In general terms, "alternative technologies" were invented and were claimed to be independent of dominant technologies. There is no easy definition of these alternatives; however some instances are the bicycle instead of the motor car, wooden instead of concrete houses, solar panels instead of electricity for heating water.

A Verification: Pluralism in Stating the Inertia Principle

The clearest demonstration that science as a whole diverges with regard to its formal foundations is obtained by an examination of the inertia principle, which, being the starting point of the most important theory of traditional science, Newton's mechanics, represents the beginning of modern science.

Descartes-Newton's version is: "Every body perseveres in its state of being at rest, or of moving uniformly forward in a straight line, except insofar as it is compelled to change its state by a force acting on it" (Newton, 1687: 12). An alternative version was suggested by (again!) L. Carnot (1803: 49): "Once a body is at rest, it will *not move* by itself; once it is in motion, it *will not change* either its speed or its direction" (where *changing* and *moving* are the negation of "rest," the only situation which does not require scientific explanation).[32] It is worth noting that L. Carnot's doubly negated sentence (e.g., *not move*) does not have a corresponding positive word in science; in fact, in order to be able to express the same idea positively, Newton makes use of the verb "to persevere" (or sometimes "to continue"), which is clearly a moral and animistic word. Here we have a drastic alternative about which kind of logic, either classical or nonclassical, shapes a theory. Being a basic principle, the version of the inertia principle determines the entire organisation of the subsequent development of the theory; Descartes-Newton's version is an AO of mechanics, whereas L. Carnot's version a PO.

In addition, it is worth noting that Newton wrote: "Every body." These two words include even the bodies that we will discover in the future; here we recognise an *infinity in action*. He also appeals to infinity in action when he wants to establish with total accuracy—an accuracy which implies the actual infinity—when a force is impressed upon the body or not, if the body is absolutely at rest or not, if the motion is perfectly rectilinear or not, and perfectly uniform or not; and if the distance that the body covers is infinite or not (Hanson, 1965). All these qualifications require such accuracy as to sever the null value of each of the above magnitudes from any other value, however little; they require not an unlimited infinity, but an actual infinity. All the above qualifications are avoided by Carnot's version of the inertia principle, which instead includes only the typical properties detectable by experimental physics, i.e., the only ones that are operational and calculable, and which do not use actual infinity. Being a basic principle, the inertia

[32] This remark was made by Hanson (1965) who ingeniously produced an almost exhaustive analysis of the inertia principle. See also Drago (1988).

principle establishes the kind of mathematics of the subsequent development of the theory; Descartes-Newton's version mathematics with AI and L. Carnot's version of mathematics with PI.

In the history of mechanics this kind of alternative theory of mechanics had already been put forward by Leibniz.[33] He moreover added two basic ideas. First, in the human mind there exists "two labyrinths of human reason." One is about infinity, either actual or simply potential. We recognise that in our times the first labyrinth was formalized by the option concerning the kind of mathematics, either classical or constructive. The other dilemma is between "law" (i.e., to behave according to some a priori principles) and "free will" (i.e., to investigate heuristically). We recognise that at the present time this second labyrinth is formalised by the option concerning the way of organizing a theory, either by using a few abstract principles from which all laws may be rigorously derived, as theorems, by means of classical logic; or organizing a theory to search inductively for a new method to solve a general problem.

Leibniz (1686) also suggested that there are two basic principles of the human mind: the principle of noncontradiction and the principle of sufficient reason. The latter was stated by him with the following words: "*Nothing* is *without* reason";[34] really, a doubly negated sentence. We recognise that he was suggesting the two basic principles of the two different kinds of logic, respectively the classical and the nonclassical. In short, the two dilemmas that Leibniz cleverly recognised represent, although in no more than philosophical terms (i.e., infinity and organization), the two above-illustrated basic options, which at the present time are well formalized in, respectively, mathematics and logic.

Every theory chooses one of these two options. Being two independent dimensions, when we cross them we divide the space of all theories into four quadrants and each may be considered to represent a particular *model for scientific theory*.[35] Being severed one from the other by mutually conflictual

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[33] Drago (2001, 2003). In retrospect, Leibniz' mechanics lacks two theoretical improvements: the introduction of the index of elasticity and the principle of virtual velocities (which was formulated by Bernoulli one year after Leibniz's death).

[34] As an improvement of Leibniz' philosophy of science, see Drago (1994). In particular, Popper's celebrated philosophy of science is interpreted as a new attitude inasmuch as it first made an implicit use of non-classical logic (Drago, Venezia, 2007).

[35] See Drago (1996). A crucial philosophical notion proves to be the incommensurability between two theories (Drago, 1999). Nowadays many think of science as a va-

choices, these models represent a well-rooted pluralism in science. Moreover, the two options provide the human mind with the cardinal points of a compass by which it is oriented among the innumerable theories of the modern world. In such a way one obtains an answer to the problem put by Lanza del Vasto; a person can obtain a comprehensive knowledge of science.

Away from Monopolies in both Science and National Defence

The general conclusion is that, despite the changes brought about by the French Revolution, for two hundred years the scientific community refused to consider the internal conflicts in science. Scientists tenaciously presented Science as a monolithic construction with no possible alternatives, i.e., as the only possibility for all activities and human thought to be "at peace." This undisturbed science claimed to be capable of reconciling all social conflicts: for example, in the early years of the 20th century, Science claimed to be capable of reconciling social conflicts in the factory system by introducing Taylor's scientific principles for equitably evaluating human labour; between the 50s and the 80s science claimed that it could reconcile the East-West clash through scientists' superior formulae on disarmament. In the 70s science imposed nuclear power; in solving the problem of energy planning, because it will guarantee mankind universal welfare and therefore peace. These solutions (the choice of nuclear power) were justified by the belief that science is making the greatest rational effort possible to avoid such internal conflicts.

Let us recall Galtung's important distinction between three types of violence: personal, cultural and structural. We see that the dominant science falls within cultural violence, not only because it justifies structural violence but also because it monopolizes the truth by means of its results, which are obtained regardless of human life, presenting itself as the only, unquestioned solution to human problems. The *violence of science consists, more than in justifying structural violence and war, in its claim to monopolise the truth on any subject, including wars*. All of which was dictated by the motto (which parallels the old Catholic Church's motto: "*Nulla salus extra hanc Ecclesiam*" (No salvation outside this Church), which monopolises souls "Nulla ratio extra hanc scientiam" (No reason

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riety of "scientific models" by means of which one sketches reality. In the present paper the word "model" has a more precise meaning; here, there are only four models, each having its own peculiar features, which can be traced back to a pair of choices regarding the two options, which constitute the foundations of science.

outside this science), which monopolises human reason.[36]

And indeed, notwithstanding the scientists' formulae, the factory conflicts, the East-West clash and the energy problem have persisted, showing that historically the initiatives of modern science look like a huge, terrible deception, even a form of subservience to a super-human power, as Lanza del Vasto suggested.

What I have shown above regarding the foundations of science leads precisely to the opposite conclusion of the belief in peaceful science; i.e., *the fundamental nature of science is conflict*, owing to the options regarding its foundations. In the previous sections I argued that at least through the different versions of the inertia principle, science does not have a monopoly on truth; every single scientific theory (even mechanics) is divided in formally alternative formulations.[37]

But even at the present time the dominant science hides such a conflictual nature by presenting one truth only, which actually is just the truth of the dominant model of scientific theory, which in turn corresponds to the dominant power in society. Thus it is necessary to dethrone the cultural violence which is operated by science which monopolizes truth and claims, in a pre-conceived manner, to bring peace. In order to understand how to achieve peace we need to find a new scientific approach which will generalize the solutions to conflicts concerning the foundations of science; i.e., we have to change from the paradigm of the monopoly of the truth to the pluralism of the four models of scientific theory.

Formalising the Alternative in National Defence and in Conflict Resolution

In the last decades several authors have supported the idea of an alternative to destructive nuclear capacity. Some of them even proposed a nonviolent strategy in national defence; against nuclear weapons they set people's noncollaboration and nonviolent mass demonstrations.[38] The 1989 nonviolent revolutions against the Yalta division based on nuclear threat occurred in both China and successfully in Eastern European countries.

[36] My motto sums up the paper by Feyerabend (1984).

[37] Of course, alternative science does not concern experimental laws, but only the foundations of a scientific theory; i.e., the mathematical techniques for formalising experimental laws, the theoretical principle for understanding them systematically, the organization of them, and the logic for arguing about them.

[38] Let us recall King-Hall (1958). Then nonviolent defence was supported by Boserup, Mack (1974); Ebert (1981); Galtung (1984); Sharp (1985); and Drago (2006).

However, going beyond historical events, is there a possible alternative rationality to that underlying both military institutions and its conflict resolutions? What kind of rationality would it be?

Let us remark that, owing to the mechanical effects of military technology (even those involving other scientific theories, i.e., chemistry, electro-magnetism, nuclear theory, etc.), the military appeals to the rationality of the dominant mechanics.[39] But previously we saw, through the two versions of the inertia principle, that there exists an alternative in mechanics; and, more in general, there are alternative formulations for each scientific theory.

A possible objection is that L. Carnot's alternative inertia principle, because it belongs to a mechanics based on impacts, necessarily concerns violent events. But the history of impact theory in physics is almost unknown.[40] At the beginnings of modern science Wallis suggested that in order to formalise the impact of bodies one had to refer to the ideal model of a perfectly hard body, whose shape never changes. (Newton agreed; he thought that God created the world that was constituted by hard bodies, which in time were transformed into soft bodies.) The perfect hardness of the ideal body did not allow resilience; hence the conservation of energy, as a general law, was considered invalid for two centuries.

But Leibniz objected that in human relationships it is desirable to behave flexibly; hence, the most suitable model of the theory of the impact of bodies is the perfectly elastic body. Due to its resilience, the impacts among bodies of this kind conserve energy and other quantities (momentum, momentum of momentum) that the bodies have in common, so that in the new idealisation the impact is no longer a macho clash, but a mutual exchange of these three common quantities. The birth of thermodynamics (1850) was necessary for the conservation of energy to be established as a general law, and, as a consequence, Leibniz's model of elastic impact. Here we have an instance of positive scientific progress promoting nonviolence, since Leibniz-L. Carnot's mechanics, which is based upon the elastic impact, is a nonviolence-oriented theory rather than the Newtonian theory of hard bodies which is a macho-oriented theory of impact.

Is this kind of rationality relevant to national defence? One of the greatest strategists of all times was (again!) L. Carnot. His strategy was an exclusively defensive defence, which relied upon the use of strongholds,

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[39] On mechanics and social thinking, see Haret (1932); Freudenthal (1986).

[40] For the basic notions, see Scott (1971). For Leibniz' basic remark see Leibniz: Letter to Lambert van Velthuysen (1671). For general considerations see Drago (1996).

since they "oblige the enemy to fight against bastions and walls, rather than human beings."[41] Moreover, he theorised strongholds as machines, to which he applied his formula for the highest efficiency, based upon the conservation of energy.[42]

Surely, after the failure of the Maginot Line L. Carnot's defensive strategy has to be changed. But we can retain L. Carnot's basic scientific notion, that of the greatest efficiency. It is determined by acting in a reversible manner; i.e., never perform an action that cannot be subsequently reversed without loss of work. Such a notion constitutes a representation of the gentle way that is necessary to solve a conflict through consensus. In weaker terms, this imperative constitutes the precautionary imperative, which is strongly supported by the ecologist movement.

This notion of maximum efficiency was then applied by his son, Sadi, giving rise to thermodynamics. By going beyond S. Carnot's partial results, we recall that in thermodynamics the greatest efficiency means the minimum of entropy change ($\Delta S = min$). This idea was already stated in the social sciences as the "thermodynamic imperative" and it was emphasised as being able to address the whole of social life (Linsday, 1963). When we apply this imperative to conflict resolution, in specific wars, it dictates the minimum cost of human lives since the death of a human being is the most irreversible process (Drago, Sasso, 1993).

Moreover, given that entropy is the notion that approximates most to the notion of the disorganisation of a system, we can translate the above formula as the minimum of change toward disorganisation in the system. Now such an imperative no longer implies the defence of something material, i.e., the stronghold, but of democratic social institutions: precisely what the German term for alternative defence (*Soziale Verteidigung*) emphasises. In short, such a scientific formula appears to human reason to be the best imperative even with regard to national defence.

Which kind of general rationality then results? First, the rationality of making use not of absolute tools (AI), such as nuclear weapons, but above all interpersonal relationships, which are merely unlimited tools. Secondly,

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[41] It is the main notion of L. Carnot's "Eloge de Vauban" (1985).

[42] This formula states the equality of the work done from the outside and the work of resistance performed the machine; work being defined as force times velocity times time, we have the formula $FVT=fvt$. From it one sees that the main advantage of a stronghold is to oblige the besieger to act more rapidly than the besieged, so that a smaller number of besieged persons are able to resist a greater number of besiegers.

the rationality of the alternative in organisation (OP), which in social terms means a self-reliant organisation that aims to solve an important social problem: in our case, a people's defence.

It is not so surprising that this kind of rationality was anticipated by some of the greatest strategists: Sun Tzu, L. Carnot and Clausewitz. They wrote books illustrating their strategies and wanted, unlike Napoleon, to share the strategy of the chiefs with the people, down to the humble soldier. Moreover, they all posed the problem of the best strategy to be chosen, the criterion for which was the saving of human lives. Furthermore these books are full of doubly negated statements; that is, they argued with that nonclassical logic which is necessary if a new method of solving a problem is to be found.[43]

We thus confirm what Gandhi often repeated, that nonviolence is a science that is even older than Papin's invention of steam pressure power.

Over the last few decades a radical change of this kind has begun in our way of reasoning, deriving from a notion from the history of science. According to Kuhn, changes of paradigm do occur after all. The historical change that should take place today in national defence may be defined with the following phrase: "Peace as a change of paradigm" (Nagler, 1981). The present paradigm is the arms race and the achievement of maximum destructive power. The anomaly is constituted by the threat of an Armageddon as the result of the application of this paradigm by two nuclear powers. Fortunately, a new model of conflict resolution is already known and was pointed out by great scientists (Einstein, Born), i.e., nonviolence. Indeed, it suggests an empirical method for solving conflicts through "experiments with truth," as Gandhi put it. Using a method that we have already seen in Freud, against the instinctual idea "He is my *enemy*," it sets its doubly negated sentence: "It is *not* true that he is my *enemy*." By putting it into different words, we have seen in the above that the very word "nonviolence" implies a completely different logic.

This radical change in the cultural paradigm of collective defence was already recognised as a need by the highest political World institution. UN Secretary-General B. B. Ghali (1992) instituted the Corps of civil Peacekeepers and civil Peace-builders which were to be considered on a par with military bodies. The paradigm change began from that date on; in other words, a period of trans-armament—a period of democratic struggle between the

[43] These strategies are analysed in some papers edited in Italian; they are quoted and summarised in Drago (2006).

two main models of defence—began, at least in principle, at the level of world politics. At present, we are preparing the beginnings of trans-armament within each State.[44]

A New Relationship Between Ethics and Science

As a consequence, there is a new relationship between science and ethics. No longer is science an absolute value, to which ethics is subordinate. When a scientist constructs a scientific theory, at the very start he makes two basic choices, respectively on the kind of infinity and the kind of organisation; due to these choices, ethics comes first, science second. As a consequence, Tolstoy's question is answered; the traditional science claiming to come before ethics is dethroned, and science is subordinate to ethics. In the following Table I summarise the relationships between science and ethics according to both the past (i.e., Western) attitude and the nonkilling attitude.

Table 1. Western and nonkilling attitudes to both science and conflict

	Western attitude	**Nonkilling attitude**
Science	"One" science, i.e., *Unity* of science; unresolvable conflicts between scientific theories do *not* exist	Among scientific theories there exist conflicts which are *unresolvable*; pluralism even in science
Ethics	There exist human conflicts which are *unresolvable unless* the opponent is destroyed	It is *impossible* for a human conflict *not* to be resolvable, owing to the *Unity* of mankind

Let us remark that the dominant Western view of science requires the belief in its Unity. This belief never will be verified, since it refers to all times to come; it is an absolute belief. In comparison, the belief in the Unity of mankind, which should be applied to conflict resolution, is more suited to the life of humanity; in short, it is a more valid value for mankind.

The same conclusion is reached when we compare the costs of the two beliefs. With the former the citizen is simply required to delegate to scientific experts, allowing them to bring about the scientific destruction of an indeterminate number of human beings; while with the latter, the citizen, doubting the absolute value of mankind's intellectual constructions, involves his/her personal life in finding the best solutions to collective conflicts.

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[44] Juridical statements similar to the main sentences of *Agenda for Peace* have been approved by the Italian Parliament: Laws 230/1998 and 64/2001.

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Why Don't I Take Military Funding?

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I don't take funding from military agencies. Why not?

Mostly it's a testimony that it's possible to have a successful career in computer science without taking military funding. My position has its roots in the Vietnam War, when I was a conscientious objector, did alternative service instead of submitting to the draft, and joined the Society of Friends (Quakers). During the 1980s and 90s, the position seemed to lose some of its urgency, so it became more of a testimony about career paths.

Since September 11, 2001, all the urgency is back. The defense of our country is at stake, so this testimony becomes critical. In short, I believe that nonviolent methods of conflict resolution provide the *only* methods for protecting our country against the deadly threats we face in the long run. Military action, with its inevitable consequences to civilian populations, creates and fuels deadly threats, and therefore *increases* the danger that our country faces.

I will come back to this, but first some other thoughts.

How did you get started with this?

In 1978, after completing my PhD thesis on cognitive maps, I found that the only funding agency that was interested in supporting my research wanted to build smart cruise missiles that could find their way to their targets. This was not what I wanted my life's work to support. So I changed areas, and started working on AI in Medicine, which led to some very productive work on qualitative reasoning about physical systems with incomplete knowledge.

Well before that, I had been a conscientious objector to the Vietnam War, and had done alternative service to the draft from 1970 to 1972 before starting grad school. Since most of my graduate studies were funded by an NSF Fellowship, I didn't think much about military funding and AI research at that time. After finishing my PhD, I did a year of post-doctoral research funded by a grant that Al Stevens and I negotiated directly with Craig Fields at DARPA. It was at the end of that year, looking for continuation funding, that I confronted the cruise missile scenario and had to decide what my research life is for, and who I am willing to have pay for it.

But how can you fund your research?

Defense Department agencies like DARPA, ONR, AFOSR, and ARO are certainly among the larger pots of money out there, and I have put these off limits for myself. I have had funding from NSF, NASA, and NIH instead. There is a State of Texas Advanced Research Program that has supported several of my projects. And I have had small amounts of funding from several companies such as Tivoli and IBM.

These other agencies typically don't provide grants as large as one can get from DARPA, for example. So, there are limits to the size of research group I can have. With very few exceptions, I have decided that I will fund only grad students, and not try to support research staff or post-docs, who are *much* more expensive than grad students. I have sometimes had quite a few grad students, and a large lab, but the funding requirements remain moderate.

When I first decided to refuse military funding, I felt I would be making a serious sacrifice. As it has worked out, research money has sometimes been tight, but never disastrously so. And as I watched my colleagues dealing with DARPA's demands for reports, PI meetings, bake-offs, delays and reductions in promised funding, and other hassles, I began to wonder whether I hadn't gotten the best side of the deal after all.

It's important to remember that the bottom line in research is productivity of ideas, not dollars brought in. At some point, the hassle of dealing with an agency may decrease one's intellectual productivity more than the money they provide increases it. But that's a practical issue, not a matter of conscience.

The bottom line here is that refusing military funding puts a limit on how large a research budget I can sustain. But that's not the same as limiting my intellectual productivity.

What's wrong with taking military money? They have funded lots of great research!

Certainly so: AI and the Internet being two large categories of them.

That kind of research is enormously important, and I am glad that our society finds a way to fund it.

However, the goal of the military is to settle international conflict through violence. As a friend of mine was told by a general, "Everything we do ultimately has one of two goals: killing people or destroying things." I believe that this attitude towards conflict resolution has become a "clear and present danger" to our world and our country. The world has become so small through transportation and communication, and our weapons have become so deadly, nuclear and biological, that we cannot afford the illusion that violence makes us safer.

A true defense of our country would require both resources and research into nonviolent conflict resolution methods. Both of these exist, but are starved compared with the technologies of warfare.

My stand is a testimony, saying "I will not devote my life's work toward making warfare more effective." I am also trying to show, by example, that one can be a successful and productive computer scientist, even while taking this stand.

Do you try to keep others from taking military funding?

No. Mine is an individual testimony, and each person makes an individual decision about how they will spend their life's work.

Many years ago, when William Penn converted to Quakerism and pacifism, he was troubled by the thought of having to give up the sword that he wore, a great honor at the time. He asked George Fox, the founder of Quakerism, what he should do. Fox told him, "William, wear thy sword as long as thee can."

Why not use military funding for virtuous research?

First, it's a testimony, and a testimony has to be clear and visible to be useful. Certainly there is virtuous research funded by military agencies. Many colleagues whom I respect highly take this approach and I honor them for it. But it doesn't send a clear message to others, and I want to do that.

Second, there's a slippery slope. You can start with a research project as pure as the driven snow. But a few years later, money is tight in the pure research category, and you get offered a research grant from a more applied office within the same agency. Do research on the same topic, but frame it in terms of a military mission. Step by step, you can slide into battlefield management and smart cruise missiles. One thing that makes the slope so slippery is that you have accumulated responsibility for a lab full of graduate students, and the consequences of a major drop in funding will be even more painful for them than it is for you.

Another thing that makes the slope slippery is that military problems are often very interesting. It's easy to get caught up in an interesting technical challenge, and lose sight of what is actually happening: that the objects in the plan are human beings, and that the actions that are being planned are to kill them.

With a little cleverness, you can find similarly fascinating problems in the space program, where there is NASA funding, or in the economic sphere, where there is private funding. Or in other areas of science, where NSF and NIH do the funding.

Is everything the military does tainted?

Certainly not. Most people don't realize that the US military is perhaps the largest educational institution in the world. It provides valuable academic and vocational training to a huge population, many of whom might not have access to it otherwise. It also provides training in character and discipline that are hard to match elsewhere.

There are even signs that the professional military is reaching a clearer understanding than civilian policy-makers of the weaknesses of violence, and the strengths of nonviolent approaches to conflict resolution. We may be moving toward the day when trained, disciplined soldiers will be able to move into a situation of conflict and restore civility and peace without loss of life.

That's a day worth working for.

The military can use your research anyway, from the open literature. Why not have them pay for it?

Many things have both good and evil uses. If I create new knowledge that can be used for either good or evil, and present it and evaluate in terms of the good purposes, then someone who converts it to evil use bears that responsibility. If I present it and evaluate it in terms of the evil purpose, then I make it that much easier and more likely for it to be used for evil. I must then bear the responsibility.

This argument is not very robust against speciousness and rationalization. If I make a rapid-fire machine gun firing armor-piercing bullets, and present it and evaluate it for the sport of target-shooting, I am deceiving myself (or more likely, not). Whoever funds the work, I am responsible for anticipating who is likely to use it.

At the same time, if I develop a new scheduling methodology for industrial processes, the military is likely to benefit, since it includes many industrial processes. But peaceful economic activity will benefit more, and the military benefits only in the aspects it shares with peaceful enterprises.

Do work that makes the world a better place. The fact that the military becomes better too is not a problem.

Should I consider military involvement when I choose a graduate school?

Probably not too much, but keep your eyes and ears open when you visit the different schools. Most top graduate schools in computer science will have substantial amounts of military funding, but most will also have faculty who are seriously concerned about the militarization of research. You should look for a balance that leads to productive discussions, rather than a "party line."

Look for faculty members who can guide you in directions you want to go. This means looking for both intellect and integrity.

Are you ever tempted by large military grants?

Yes, of course. Recently a friend of mine, whom I respect highly, took a leadership position in a major agency, and created a research program I find enormously attractive.

After struggling with the question for several weeks, I decided that the need for testimonies like mine was becoming greater, not less, in these difficult times, so I have reluctantly passed on this possibility. Sigh.

The fact that a course of action is right does not necessarily make it easy.

What about September 11? We're under attack!

Our country suffered horrific losses from a terrible attack. The criminal gang responsible must be brought to justice, and we must protect ourselves against possible future attacks. However, violent actions taken in the name of defense against terrorism are very likely to increase the likelihood and magnitude of future terrorist attacks. We need a combination of short-term vigilance and protection, and long-term efforts to reduce the problems that breed terrorism, both in nonviolent ways.

A question from a student

> I am writing to ask for advice. I am one year away from graduating with a BS in computer science and am considering graduate school. When I started looking around my department for some research to get involved in, I was surprised to find how much of it relies on military funding. This lead me to find your essay on why you don't take military funding. I share your views and as tempting as it is, and as much as I feel I'm missing out on some really interesting projects, I've decided I will not work on anything that receives military support. So, I'm hoping you can offer further advice on how and where to look for grad programs. How do I find other faculty who share this concern for the militarization of research? Will I find more options overseas? How and when do I tell prospective schools about my decision?

Let me applaud you for your principled stand. As you have surely noticed, these are times that require good people to stand up and be counted, publically.

Although I did alternative service as a conscientious objector during the Vietnam war, I did not decide to avoid military funding until a year after completing my PhD. I was fortunate to have obtained NSF and Danforth Fellowships that funded almost all of my graduate studies. After I became a faculty member, I got quite good at raising grants from NSF, NIH, NASA, and other places.

You will need to do similar things, just starting earlier. There are a number of competitive fellowships for graduate study that you can apply for as an individual, and carry with you to your choice of graduate school. Many of these, like the NSF, the Hertz, the Gates, etc, are very competitive. It is a big advantage in such competitions to be clear on your own beliefs and your own priorities. Make sure you can express yourself in a clear and compelling way, and you have a significantly better chance. If you succeed in obtaining your own funding, it makes you much more desirable at top graduate programs.

A couple of useful quotes for this enterprise are, "Momma may have, and Poppa may have, but God bless the child who's got his own!" and "Be wise as serpents and gentle as doves." (Look them up.)

Even if you don't get this kind of fellowship, there are plenty of options for supporting yourself through graduate school without military funding. You can be a teaching assistant; you can be a research assistant to a faculty member with other kinds of funding; you can find work maintaining computers for a lab in another department; you can get a part-time outside job; and so on. Generally, rejecting the single largest funder will require you to be more creative about looking at other funding possibilities. This creativity will serve you well. One of the fortunate things about working in computer science is that you have a practical skill that is needed by people in many different areas, and they are often willing to pay for your services.

On finding faculty with similar beliefs, I would suggest just asking. A quick scan of each faculty member's web page, and especially the acknowledgements on publications, will tell you where they get their funding. Find a few people whose research you find attractive who have nonmilitary funding, and talk to them.

Personally, I find it most productive to be clear and straight-forward, without being judgmental or confrontational. You will very likely find plenty of people who are very sympathetic to your values, but who aren't willing to make what they perceive as too large a sacrifice. In my personal opinion, it is more important to encourage people to see their choice of work, how it's funded, and what it's used for as an important moral decision that must reflect their own fundamental values, than to pressure them to make the same moral decisions that I have.

I doubt you will find better options overseas. I believe there is generally less funding available outside the US, and little of that would be available to a US student. There are some very fine graduate schools in other countries, but on average, the US has the best graduate schools in the world. Again, personally, I love this country, and I want my work and my life to help strengthen its good parts and help fix its problems. So I wouldn't want to leave.

How and when to tell is another judgment call. It depends on your own style, and how vocal a testimony you want to make. You may legitimately decide that this point is not relevant on the application for graduate school, or on the other hand, you may feel that it is central. You are not obliged to explain or justify every belief you have, however strongly held or controversial, to everyone you meet. You have to decide when you think it is relevant.

A final point. I think you are doing a good and noble thing. Following this path will be demanding, and maybe quite difficult, but I believe and hope it will also be rewarding in many ways, including practical ones. However, getting the education you need to make the best use of your gifts through the rest of your life is also an important value. You should not participate in activities that you believe are morally wrong, but there may be times in your life when preparing yourself for your future takes priority over making a visible testimony. There will be time and need for that later, you can be sure.

With my best wishes,

Ben Kuipers

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