Engineering for Peace

Challenges and Opportunities

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Abstract—Engineers of the 21st century need to be more than providers of technical solutions. They must also play an active role in peacebuilding, peacemaking, and peacekeeping efforts. Their work contributes to Track 2 or citizen diplomacy. This paper discusses the value proposition of using a systemic approach to positive peace and the importance of developing programs such as peace engineering to provide engineers with the attitude, skills, and knowledge necessary to work in complex and difficult settings in their lifetime. There is an urgent need to develop a comprehensive body of knowledge and a community of practice in peace engineering. The engineering profession must take the lead in creating *a peace industrial complex* so powerful that it will disturb and replace the current war industrial complex.

Keywords—Peace engineering; systems; positive peace; body of knowledge; engineering diplomacy; peace industrial complex

I. Introduction

Engineers are called to play an active role in addressing global problems and challenges faced by humanity. They include conflict and human rights violations; terrorism; human migration and refugee crisis; climate change; poverty; insecurity in water, energy, and food resources; land tenure issues; inadequate shelter and uncontrolled urbanization; pollution and environmental degradation; poor communication and transportation; and transboundary issues, to name a few. All these problems share similar characteristics. First, they are complex, ill-defined, and messy and are characterized by different degrees of uncertainty, ambiguity, and unpredictability. As a result, these problems do not have clear and unique solutions, and cannot be completely addressed using the deterministic tools used in science and engineering over the last century. They can only be addressed using more recent tools derived from system and complexity sciences. Second, all problems mentioned above are multidisciplinary and stand at the crossroads between science, technology, and engineering (STE) on the one hand and societal/economic/ environmental issues on the other.

As discussed in a companion paper [1], the engineering profession must embrace a new mission statement for the 21st century which is to contribute to the building of a more sustainable, stable, and equitable world by addressing the global problems mentioned above. The National Academy of Engineering reminds us that "A world divided by wealth and poverty, health and sickness, food and hunger, cannot long remain a stable [and peaceful] place for civilization to thrive" [2].

More specifically, engineers have an ethical and professional obligation to develop solutions to meet the basic needs of all humans for security, water, sanitation, food, health, energy, transportation, communication, as well as to protect cultural and natural diversity. By meeting these needs, it is possible to envision a world where all humans have fulfilling lives, meet their basic needs, and live with dignity and at peace. More than ever, engineers have a critical role to play in contributing to a more peaceful world and in contributing to a peace industrial complex that is better to the world's economy and to populations than the current war industrial complex. This new mission statement requires engineers to acquire new skills over their lifetime and become more aware of the consequences of their decisions in the design, management, and operation of projects in different socioeconomic, cultural, and political situations that could create division, conflict, and possibly violent disputes.

It is not the intent of this paper to discuss the different definitions of peace and what represents a peaceful world. The reader is referred to the conflict management and peace studies literature and to the book titled *Peace Terms* [3] published by the U.S. Institute of Peace for the actual definitions of peace-related concepts. This paper discusses more specifically the value proposition of using a systemic approach to positive peace; the contribution of engineers to peacebuilding, peacemaking, and peacekeeping efforts; and the importance of developing programs such as peace engineering to provide engineers with the attitude, skills, and knowledge necessary to work in complex settings.

II. Positive Peace

In the conflict management and peace studies literature, peace appears as a general concept that can mean different things to different people. As noted by Diamond and McDonald [4], peace can be analyzed as a state or process whether one is interested in peacekeeping, peacemaking, and/or peacebuilding. One thing for certain is that "peace is not…a measurable commodity. It must be seen instead as a potential, a possibility, an ever-changing condition...a direction in which to head, one step at a time" [4].

Peace and other development-related concepts such as health, well-being, sustainability, or resilience are difficult to conceptualize. The peace research literature often refers to the work of Johan Galtung who pioneered the concepts of negative and positive peace starting in the early 1960s; two aspects of peace whose definitions have evolved over time [5]. In short, negative peace relates to an *absence* of war and [direct, organized] violence; something undesirable (personal violence) ceases to exist. Positive peace relates to a *presence* and *prevalence* of positive attributes, conditions, and priorities toward promoting "social and economic justice, environmental integrity, human rights and development" [4] that contribute to a structural "integration of human society" [6]. A useful analogy suggested by Galtung is that negative and positive peace are to peace what *curative* and *preventive* measures are to health. The security of water, energy, land, and food resources, shelter, health, access to skills and resources, rules of law and good governance, justice, equity, and addressing conflict in a constructive manner are as important for positive peace to unfold as the absence of personal direct violence.

Several institutions have tried to capture the multi-dimensional aspect of positive peace. For instance, the Institute for Economy and Peace (IEP) in Sydney, Australia defines positive peace as "*the attitudes, institutions, and structures that create and sustain peaceful societies.*" It creates "an optimum environment in which human potential can flourish" [7]. According to the IEP, this optimum environment is founded on eight interdependent pillars: "well-functioning government; sound business environment; equitable distribution of resources; acceptance of the rights of others; good relations with neighbors; free flow of information; high levels of human capital; and low levels of corruption." The IEP has introduced a Positive Peace Index [7] consisting of 24 indicators to measure the level of peace, and indirectly the resilience to shock, at the country level. A Global Peace Index was also introduced [8].

Another framework that captures the multi-disciplinary aspect of positive peace was proposed by Diamond and McDonald [4]. Their Multi-Track Diplomacy framework is based on nine tracks that are assumed to contribute to positive peace: (1) government; (2) non-government; (3) business; (4) private citizen; (5) research, training, and education; (6) activism; (7) religion; (8) funding; and (9) communications. Track 9 is interpreted as linking the other eight tracks.

Both the IEP [7] and Diamond and McDonald [4] frameworks share many things in common. They both acknowledge the multi-dimensional and multi-disciplinary aspects of positive peace. They also recognize that the different components contributing to positive peace are interconnected. In addition, they acknowledge that a systemic approach to positive peace is more appropriate than assuming that the components act independently of each other in creating peaceful communities.

Finally, both frameworks also share similar limitations. They are rudimentary in their system approaches to peace and fall stop short of exploring in depth the application of existing soft and hard systems tools to capture the systemic nature of positive peace. In addition, they fail to recognize *explicitly* the contribution of science, technology, and engineering (STE) to creating peaceful communities. That contribution could be added, for instance, to the framework of Diamond and McDonald [4] as *Track 10: Peacemaking through STE.* It would refer to the community that provides the STE knowledge necessary to understand the interaction of people and their environment prior to, during, and after conflict.

III. A SYSTEMS APPROACH TO PEACE

Peace can be defined as a process (not discussed here) or, as suggested by Galtung, "a synonym for stability or equilibrium" [9]. In this paper, we consider positive peace as a state of stability or equilibrium emerging from multiple system interactions in a community landscape. That state is necessary for human/social and economic development to unfold. As often quoted in the literature, there cannot be any development without peace and there cannot be any peace without development.

In general, peace emerges in a community landscape consisting of multiple dependent systems (social, economic, financial, technical, environmental), nested subsystems, and involves multiple actors. The landscape represents a space of possibilities subject to a wide range of enabling and constraining factors. With that context in mind, positive peace can be interpreted as an *organizing principle*, and an *emerging state of dynamic equilibrium in the processes of interaction between a population (social system) and the various systems of the community landscape upon which it depends*. This definition builds on a definition proposed by Ben-Eli [10,11] for sustainability which is defined as "a dynamic equilibrium in the processes of interaction between a population and the carrying capacity of an environment such that the population develops to express its full potential without adversely and irreversibly affecting the carrying capacity of the environment upon which it depends." These two definitions show that positive peace and sustainability are intimately connected and acknowledge their dynamic and time-changing nature.

In the context of community development, a systems approach to positive peace has a strong value proposition. More specifically, it helps policy makers and development aid practitioners to:

- see community landscapes in wholes instead of snapshots;
- sense how well parts of the landscapes work together and form structures and patterns;
- acknowledge relationships between landscape components from multiple perspectives, including circular causation in addition to traditional cause-effect linear causation;

- look at community events not as separate from each other but instead as parts of patterns of behavior, which themselves are created by some internal structure resulting from patterns and modes of thought;
- understand the dynamic, adaptable, unpredictable, and changing nature of community life including the effect of time and delays (information and materials);
- understand how one small community event can influence another (positively or negatively) and the associated consequences of such interactions;
- identify leverage points in the community landscape, i.e., critical components and/or links where certain actions yield the most return; and
- understand that what is happening in the community landscape depends on where one is in the system and one's attitude toward and perception of that system.

Because in systems, structure controls behavior [12], this implies that behind the overall behavior of a community and its current state of positive peace and development, there ought to be a responsible underlying structure. In practice, the challenge becomes that of identifying that structure. The rationale behind this *inductive reverse analysis* is that if structure could be determined, places to intervene in the community landscape could be identified and interventions selected and implemented. Following the interventions, the community landscape would show a new behavior pattern and state of stability or equilibrium (peace) more in line with expectations.

The main problem with the reverse analysis mentioned above, however, is that there are no specific existing methodologies for how to do so, much less a method that would guarantee a unique, definite, and successful answer. Determining system structure from system behavior is not easy since multiple structures could explain a given form of behavior.

Having said that, determining system structure from system behavior does not have to be a random process either based only on intuition and experience. Over the past 50 years, multiple systems-based tools have been proposed in the literature to explore complex systems and comprehend their dynamics. As noted by Checkland and Poulter [13], these tools can be divided into soft and hard ones. A soft systems approach to a problem focuses more on the "systemic" process of inquiry and "problem situations," but not on the structure of the problems per se. Examples of such tools include mind maps, network mapping, problem and solution trees, and causal analysis, among others. On the other hand, a hard systems approach includes the development of systems models (qualitative and quantitative) to address the systemic *and* structural aspects of the problem being analyzed. Existing hard system tools include system dynamics, cross-impact analysis, agent-based modeling, and network analysis, to name a few.

Whether soft or hard system tools are used to model the state of positive peace and development of a community, it is necessary to have acquired beforehand: (i) a comprehensive map and assessment of the different systems, sub-systems, and groups of actors currently at play in and deemed critical to the community landscape including their inter- and intra-linkages; (ii) a clear idea of the desired states of these systems; (iii) well-articulated peacemaking- and development-related issues (defined as gaps between current and desired states) and possible stressors and constraints; and (iv) participation from all the stakeholders (e.g., community, government, outsiders) facing the issues and willing to solve these issues. It should be noted that these requirements are context and scale specific and are not easily transferrable from one context or scale to the next.

Once system models have been developed, decision makers can proceed and identify possible scenarios of intervention to address the issues, assess the intervention risks and outcomes, select the most desirable solutions using different decision-making methods, and develop implementation plans. As discussed in the book *A Systems Approach to Modeling Community Development Projects* [14], a systems approach to complex problems requires adopting an iterative, incremental, fragmented, and trial-and-error approach. It also implies that the decision makers have acquired the habits of system thinkers [15]. Further discussion can be found in the book titled *Modeling the Environment* by Ford [16] who proposes steps in system dynamics modeling of complex problems. They include: (i) problem familiarization; (ii) problem definition; (iii) model formulation by constructing stock-and-flow diagrams and causal loop diagrams; (iv) parameter estimation; (v) simulation to explain the problem being addressed; and (vi) simulation analysis consisting of sensitivity analysis and policy analysis.

IV. PEACE ENGINEERING

A. Definitions

The concept of peace engineering seems to have been introduced first by Aarne Vesilin [17,18] who defined it as "the proactive use of engineering skills to promote a peaceful and just existence for all." As noted by this author, this definition is general enough to be in sync with the general code of ethics adopted by the majority of engineering disciplines, including military engineering if engaged in activities that contribute to peace such as in post-conflict reconstruction efforts [19]. It should be noted that although the definition does not specify whether engineering contributes to negative or positive peace (as defined earlier in this paper), the papers of Vesilin [17] and co-workers [18] seem to emphasize that peace engineering is more about contributing to positive peace than negative peace.

Another definition suggested by the International Federation of Educational Engineering Societies (IFEES) considers peace engineering as "the application of science and engineering principles to promote and support peace." It recognizes the importance of the engineering profession in contributing to "a world where prosperity, sustainability, social equity, entrepreneurship, transparency, community voice and engagement, and a culture of quality thrive" (http://www.ifees.net/peace-engineering-i/).

Both definitions of peace engineering appear to be vague and do not provide recommendations as to what the body of knowledge (BOK) necessary for the education of peace engineers (or engineers for peace) should be. To the best of the author's knowledge, only two educational programs in the U.S. have started looking at the BOK. The University of St. Thomas in Minneapolis, MN has a peace engineering program "designed for engineering students interested in becoming responsible critics of contemporary societies and effective agents for positive social transformations." Students work toward a BS degree in engineering and a minor on justice and peace studies [20]. Another educational initiative on peace engineering was initiated at Drexel University in Philadelphia in 2016. Since that time, Drexel has been working on developing a BOK for a MS degree in peace engineering [21]. The program is unique as it involves the collaboration of multiple disciplines (engineering, arts and sciences, health, law, business) across the Drexel campus and works in partnership with the PeaceTech Lab in Washington, DC.

Developing the BOK of the peace engineer (or engineer for peace) requires different groups of interested parties at the crossroads between engineering and peace studies to agree first on a vision and mission for peace engineering. It also requires establishing a multi-disciplinary *community of practice* around the education, research and development, outreach, and practical components of peace enginering.

B. Discussion

There is an underling assumption in the definitions of peace engineering (or engineering for peace) that engineering work leads to peaceful solutions. This assumption necessitates some discussion since it is not always true. Apart from the role of engineering in warfare and its contribution to the war-industrial-complex, engineering has contributed to making the world a better place especially in the 20th century. There is no doubt that engineering has been an integral part of the development of human society and has contributed to building more stable and peaceful communities. Better living conditions and greater life expectancy that people experience in western countries today are the results of major achievements in medicine and engineering practice during the past 150 years. Today, our quality of life is built upon a complex and highly productive set of technological, industrial, and municipal systems and structures. Engineers are critical to building, operating and maintaining these systems and structures. Engineers also play an active role in re-building societies following conflict and disasters. Engineering is also critical to stabilizing fragile and conflict-affected societies. In short, engineers can play multiple roles and find themselves contributing to three inter-related peace contributing efforts: (i) peacebuilding by providing the necessary infrastructure so that conflicts are less likely to unfold or relapse; (ii) peacemaking by bringing different community stakeholders to agree on joint solutions especially in transboundary or conflict prone areas; and (iii) peacekeeping by being responsible for the proper functioning of infrastructure as peacekeeping operations take place [22].

It should also be noted that the engineering achievements of the 20th century have also had shortfalls. For instance, the technical successes mentioned above have benefitted only a small fraction of humanity and have had a limited impact in improving the livelihood of the most destitute people on our planet. For instance, life expectancy in many developing countries is still low and very similar to what it was in the U.S. 100 years ago. The engineering profession still has an important role to play un providing support systems to those living today in unhealthy, degrading, inequitable, and unsustainable conditions. They live at the bottom of the energy, food, water, health, shelter, education, economic, peace, equity ladders, and many other ladders. Addressing these poverty issues is necessary, but not sufficient, to prevent conflict and possibly violent disputes. The U.S. Institute of Peace and the PeaceTech lab in Washington, D.C. are emphasizing the importance of technologies, entrepreneurship, collaboration, stable governance and rules of law, social well-being, and safe and secure environment in: (i) reducing the incidence of conflicts; (ii) diffusing existing conflicts; (iii) recovering from conflicts; and (iv) preventing relapse into conflict [23].

The engineering achievements of the 20th century have also contributed to unplanned or undesirable effects of technology on natural and human systems in both the developed and developing worlds. As mentioned by Berry [24], over the past 150 years we have witnessed in the developed world the creation of a technical wonderland side by side with a technical wasteland. Multiple mistakes have been made by different branches of engineering (e.g., mining, agricultural, civil, military) that have led to air, water, and land pollution affecting the health of populations and the depreciation and collapse of ecosystems. The war industrial complex and warfare have also contributed to violent conflicts and the death of millions of innocent victims. In summary, there are many examples of cases where the engineering profession has exacerbated conflict rather than promoting peace and has not lived up to its code of ethics.

V. CONCLUSIONS

More than ever, the future of our planet and its inhabitants depend on having engineers who have the attitude, skills, and knowledge to plan, design, manage, and operate projects that lead to more prosperous, stable, and peaceful communities worldwide. Their solutions need to be sound from a technical point of view (i.e., done right), adaptable to the cultural, economic, and social context in which they work (i.e., rightly done), and developed for the right reasons.

Engineers need to be more than providers of technical solutions. They must play an active role in peacebuilding, peacemaking, and peacekeeping efforts. They may not be official Track 1 diplomats [4] but their work contributes to what is sometimes called Track 2 or citizen diplomacy [25]. To operate at the nexus between development and diplomacy (and sometime defense), engineers must complement their traditional engineering skills with "a) skills of coordination, negotiation, and communication with [multiple] stakeholders; b) the ability to take account of environmental, social, and other impact studies; and c) the ability to work in interdisciplinary teams" [26]. Peace engineering is closely related to another emerging field of engineering called engineering diplomacy (like science diplomacy) which ranges from integrating engineering in diplomacy to integrating diplomacy in engineering [27]. Like peace engineering, engineering diplomacy is still a nascent field of study whose BOK has not yet been clearly outlined.

There is an urgent need to develop a comprehensive body of knowledge in peace engineering that emphasizes the professional and moral/ethical obligation of engineers to address complex human/social and economic development issues. At a minimum, any peace engineering program should give engineering students the tools and concepts to: (i) learn who they are as global citizen engineers; (ii) become familiar with the fundamentals of conflict management and peace studies; (iii) acquire the skills necessary to work in different socioeconomic, political and cultural contexts of peace building, peacemaking, and peacekeeping; (iv) be systems thinkers and competent in using tools from systems and complexity sciences; (v) see peace and conflict with a systems perspective; (vi) be cognizant of the STE-policy nexus; and (vii) be familiar with the fundamentals of diplomacy for science and engineering.

Not only is the field of peace engineering still ill-defined today, it also lacks databases of case studies that clearly illustrate and document the links between engineering and peace science. Finally, it lacks a *community of practice* and could benefit from the establishment of a Peace Engineering Society like the existing Peace Science Society [28,29].

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