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TOWARDS AN ENGINEERING THERMODYNAMIC UNDERSTANDING OF EVOLUTION

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ABSTRACT

George Bugliarello argues that engineers should be taught that engineers and engineering practice are natural extension of biological evolution. The implication is that biological evolution both is and always has been an engineering enterprise.

In Part One, I sketch a further elucidate the modern engineering worldview by reviewing seminal contributions by Vincenti, Florman and Simon. Per hypothesis, the technological structures and functions of reality, and how they came to be as they are, can only be properly understood within an engineering worldview. This theme is not new. In Plato's dialogue, *Timaeus*, the emerging design of the universe is guided by the vision of the Architekton, the Master Engineer.

Engineering practice is, by its very nature, exploratory, seeking to move from a current state to a more desirable future state. Engineering uses the tools of the scientific knowledge to advance the aspirational values of the humanities. Being more comprehensive, the engineering worldview naturally subsumes and supersedes both the sciences and the humanities.

In the scientific representation we are 'spectators', seeking to discover the invariant laws governing 'objective' reality – 'out there'. In the engineering representation we are 'participants', embodied agents seeking to advance an emerging reality. Scientific reality is uniform, conservative, zero sum. Engineering reality is generative, recursively enabling and historically cumulative. As Dewey expressed it, we are all 'participants in the construction of the good'.

Engineering practice, and evolution, are appropriately characterized as inseparable from the ubiquitous 'problem of design'. Typical engineering design questions are, for instance: how <u>should</u> we design the irrigation of our fields? how <u>should</u> we design our houses (architecture)? how <u>should</u> we design our neighborhood and our cities (urban design)? how <u>should</u> we design our economy? how <u>should</u> we design our political system? This last broad concern with socio-economic-political design is the focus of Plato's famous dialogue, *The Republic*. The American Constitution is a design document proposing an experiment – for how we <u>should</u> live together. Engineering is concerned with how the world <u>ought</u> to be.

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As individuals, we are, each of us, engineers, in the sense that we are deciding how should we design our lives: how much time should we spend with family, how much at work, how much to commit to health and recreation, and so forth. In his second critique, Immanuel Kant emphasizes that the decisions of practical reason are about 'how should we live'. This was one of the inspirations of American Pragmatism.

Socrates suggested that the question 'how should we live' defines the most general context of life, of all understanding and seeking in the world.

In Part Two, I will argue that 'engineering practice', as characterized in Part One, is literally thermodynamics, properly understood. Oxford's Peter Atkins distinguishes two historical accounts, and two corresponding modern formulations, of thermodynamics: the Carnots' engineering thermodynamics and the Clausius-Boltzmann 'rational mechanical' thermodynamics. Engineering thermodynamics is the narrative basis of the participant engineering worldview of Part One.

The foundations of the modern engineering thermodynamics arose in the late 17th century with Leibniz's proposed meta-paradigm shift from Statics to Dynamics. Dynamics doesn't reject Statics, but is more general, subsuming and superseding.

For purposes of exposition, I focus on the mature work Lazare Carnot, Sadi's father. Benefiting from the intervening contributions of Huygens, Euler, Lagrange and Maupertuis, Lazare advanced Leibniz's research program. Lazare argues that all 'rational mechanics', today's mathematical physics, are unable to make sense of engineering practice. Quite explicitly, he proposes to develop a new more general 'dynamic engineering mechanics', and the corresponding worldview.

He begins by noting that there is a well-known principle of engineering practice that cannot be made sense of in any rational mechanics: that what we 'lose in time (velocity) we gain in power'. This entails that engineers always have a range of options in accomplishing a task (e.g. faster or slower). By including a 'time dimension', Lazare moves us from the path independent processes of Statics to more general engineering possibility space of the path dependent processes of Dynamics. The engineer always has an existential freewill albeit highly constrained by his abilities and resources. For engineers, action requires the evaluation of a range of potential paths to the future.

The necessity of making a choice necessitates that engineers always act for a reason. Outcomes are never certain. The inherent existential uncertainty in the historical narrative also means that every novel action is also in part a novel question. For both Leibniz and Lazare everything that happens in the worldview of Dynamics involves a reason. Leibniz captures this in his Principle of Sufficient Reason. Acting for a reason is acting with a purpose. And to act with a purpose is to advance some envisioned value.

Sadi Carnot's essay on heat engines is a 'simple' extension of Lazare's foundational work. For both Leibniz and the Carnots reality is composed of engines, organic metabolic engines that both perceive and seek. In other words, the world is composed of thermodynamic agent-engineers in a world of thermodynamic agency. Reality is agency all the way down, and all the way up.

'Engines' are the paradigmatic ontological representatives of engineering thermodynamics. They constitute a type of organized component that, by their very nature, cannot be made sense of within any possible zero sum 'rational mechanics'.

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