

Learning from life's principles to design for resilience and agility and engineer for sustainability

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There are certain unique properties of living systems that we are seeking to imitate in the quest to design systems and organizations with high agility, which can dynamically change, exhibit emergence, and self-organize to adapt, reconfigure and quickly respond to unexpected societal and environmental demands. Applications for such technology abound in a large variety of problem domains in our ever-changing world, since several critical problems are due to the rigid structure of our social, political and economic systems. These systems do not allow for adaptation and agility of response to unexpected, emerging needs, but rather act as roadblocks on the path to implementing effective necessary solutions. In our quest to make our world more sustainable and resilient, we need to acknowledge the limitations of our legacy of (institutional and critical) infrastructures, which were built in the industrial age. A deep understanding of the intimate mechanisms behind the properties that make a living technology “alive” will point to the need to change the cultures in our organizations and revolutionize how we live and work through a radical shift in the way we interact with (and within) our socio-politico-economic systems, as well as with the natural environment: from being constrained and dependent on technology and institutional structures to having them fuel our creativity and innovative potential in a proactive, anticipatory manner.

In an ever-growing system of systems linked by intelligent communication networks, *softbots* (autonomous software robots that emulate human abilities, such as making decisions, discovering knowledge and performing tasks on behalf of the user in cyberspace) and *nanobots* (autonomous nanomachines exhibiting human-like behaviour to perform tasks in environments inaccessible to the human, such as carrying drugs to various parts of the body through the blood vessels) start interacting to create “societies in Cyberspace.” These Cyber-Physical Ecosystems exhibit a life of their own in an emerging parallel universe, bridging the physical and the virtual, merging us with our “things,” transforming the way we live and work, and augmenting our abilities in unprecedented ways. Examples range from smart homes, grids, transportation and cities to self-reconfiguring manufacturing plants and self-deploying emergency taskforces, all relying on myriad sensors, mobile devices, software agents and human users that would build an ecosystem bringing the right skill, tool, or competence at the right time for the right task on the sole basis of local rules and peer-to-peer communication. Living technologies offer inspiration from natural systems for a new way of designing and engineering such digital ecosystems that are being interwoven into our world's infrastructures, from governance structures to critical infrastructures, endowing them with an intrinsic ability to self-replicate, evolve and adapt to support us respond to the demands of an ever-changing, unsafe and convoluted world.

Taken together, interconnected grids of communication, electricity, and transport amount to what we call “organic infrastructures” whose integrated and reliable operation will undergird development of this

century's energy-efficient and sustainable cities, hosting the institutions and technologies of transformed low-carbon economies. Living technologies will enable the deployment of such organic infrastructures for the transition to a post-manufacturing, innovation- and knowledge-based green economy and society. We envision that such constructive organic organizations designed as "living systems" merging power grids, cloud computing, smart buildings and transportation networks will advance the state of the art in the rigorous design of resilient and robust management systems for the control of resource usage in massive-scale complex systems, targeting a "clean" and "green" world. We envision that living technologies will be at the forefront in the deployment of digital ecosystems that promote energy efficiency and reduce carbon and greenhouse gas emissions in homes, offices, factories, cities, and entire urban regions; and in extremely large-scale distributed data centres that will support the next generation of cloud computing.

Above all else, however, the enormous potential stems from the lessons that we can transfer from life's successful principles to revolutionize our governance structures to reset the current dynamics of our world from its perilous (market-and-conflict-oriented) trajectory, onto a prosperous one that is sustainable and focused on human needs. Such a shift in governance is required for fuelling the generation and adoption of innovation, in all sectors and at all levels of social, and institutional and organizational structures. There is an acute need to (re-)define new indicators of wealth and social well-being that will enable this critical paradigm shift from risk governance to resilience governance. Due to the lack of adequate policy frameworks, the obstacles in implementing innovative solutions at all levels are the limited capacity of social processes to manage rapid change in institutional design, planning and public services, rather than technological innovation. Lessons from life's processes are priceless in restructuring the organization of our social processes into more fluid and organic structures that enable the manifestation of creativity through social innovation generation. Among the most critical issues that must be addressed without delay are:

- how to facilitate the *transition* from the currently disabling rigid governance structures into the necessary enabling agile policy frameworks that will transform our coercive institutional frameworks into agile, responsive and fluid ones, capable of fostering creativity and supporting innovation;
- how to design *engaging control mechanisms* that stimulate rather than oblige, transitioning the current work organization processes from contract to commitment by fuelling performance through visceral engaging architectures of participation, which, in an online gaming-like manner, infuse blissful productivity into work activities, giving an epic-like meaning to the purpose of work;
- how to design *validation frameworks* that reveal the impact of policies on the work ethics, culture and productivity in our organizations;
- how to redefine *indicators* that expose the impact of the convoluted effects of interdependent socio-political-economic factors on the current global dynamics, negatively affecting the overall wellbeing and sustainability of life on Earth;
- how to anticipate the evolution of society and the course of life under the influence of the transformative forces that change us as individuals – who in turn change our environment, which changes us – on the ever-mysterious trajectory of mankind's destiny as part of our "living," self-organizing universe.