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COMPLEX SYSTEMS ENGINEERING

In those sense earthquakes, forest fires, species extinctions and crashes of stock exchanges are similar events? All of these events can be large fluctuations that universally arise on systems that are out of balance in a critical condition. The organization of these systems does not depend on the precise nature of the things involved, but only the way the influences propagate from one place to another. Here, rare events arise from mere accumulation and later releasing stress.

Just as it is tempting to seek major causes behind the terrible earthquakes or mass extinctions, it is also tempting to search great people behind major historical events. However it is possible that the only general cause for such events is the internal organization of a critical state, which causes rare events are not only possible, but inevitable. The fundamentals of a critical state are reflected in simple statistics laws: laws of power that have no characteristic scale, revealing the absence of a "size" expected for the next event.

The discovery of universal laws in physical systems raised the hypothesis of the existence of universal laws in biological, social, and economic systems and gave rise to the physics of complex systems. You could say that is the border between order and chaos. This theoretical basis appeared the Complex Systems Engineering.

Two revolutions in science have formed the basis the of Complex Systems Engineering. The first was the work of the physicist and chemist Ilya Prigogine, who worked the Thermodynamics of reversible processes, formulating the theory of dissipative structures. His work showed that, out of balance, the equations that govern the physics are irreversible. He received the Nobel Prize in chemistry in 1977. The second revolution was the theory of fractal geometry of the mathematician Benoît Mandelbrot that overcomes limitations of Euclidean geometry.

And what would be more exactly this of Complex Systems Engineering? It should be in the field of practical features of complex systems made up of many interconnected elements relatively simple geometries in hierarchical, Fractals, often irregular. The collective behavior of such systems, their structures and sophisticated dynamic originate in elements that interact through dynamics of great simplicity. Is in the endless repetition, in large numbers, that are born the macroscopic phenomena which man observes and in which it is immersed. This is what occurs in complex ecological dynamic in natural disasters such as tsunamis, earthquakes, hurricanes, in the complex evolution of our environment, in the profound changes that man, wanting or not wanting to, will cause the fauna and flora, in agriculture. It is thus also in the plasma of the solar wind, intensely studied by NASA, ESA, and other international bodies, accompanied by the United Nations.

This is what occurs in the evolution of languages and cultures, and markets, in the ozone layer, on the outbreak of Chagas disease, dengue, tuberculosis. This is what occurs in the turbulence of our atmosphere, and the galaxies, and from the crowds, and nuclear fusion, which perhaps will represent one of the most important energy sources for human use for our children, our grandchildren. It is perhaps this that occurs in the depths of the soups of quarks and gluons that form after the formidable collisions between protons, and other elementary particles, which are caused in the mighty LHC at Geneva or Brookhaven, in the United States, or the flows of cosmic rays observed by Auger Observatory. All these manifestations of nature, of artificial systems and social systems have surprising elements in common. This is what studies the science of complex systems, in the National Institute of Science and Technology of Complex Systems, created three years ago and 36 activities bringing together scientists from 18 institutions of Brazil.

And what is the proposed focus to a Complex Systems Engineering? The practical applications of these concepts in signal processing (electrocardiograms, electroencephalograms, El Niño temperatures profiles over access to oil tanks), imaging (mammography, computed tomography, night vision, occasionally dirty boards – or, rusty cars – crossing signals in red or travelling at speeds prohibited), the automatic classification of hundreds and thousands of normal or cancerous cells. The practical applications for the optimization of fast and lots of financial operations of today's world of computational algorithms governing practice procedures in chemical and pharmaceutical industries, of traffic signs on the internet and other computer networks, and in cars and motorcycles in major cities. The list is simply endless.

One can also understand the Complex Systems Engineering as a systems engineering of systems. What already exist are systems engineering, which is applied in logistics, transport and construction systems, among other areas. What there is a systems engineering that interact with each other and that are complex. It applies not only to materials, but in financial operations and in agribusiness, for example, in that there are a number of problems that influence. In agriculture there is the problem of soil, pesticide and agricultural inputs, storage and transport, for example, so that the entire production of the Center-West region of Brazil is exported, or the Amazon forest and agricultural production is stepped up.

The agricultural production, forestry, fishing and mineral riches of the Amazon is a sum of complex systems. There is no way to develop sustainable production without understanding their ecology in itself a complex system. What about the sustainable and economic exploitation of its biodiversity? And the energy use of its immense hydrograph? The development of this immense territory depends on knowledge of complex systems.

Are systems involving many variables. And this can worsen if the interaction between these variables is nonlinear. For example, in the agribusiness, bending corn production if the price of transport of the quadruple system logistic difficulties of Brazilian front roads, there appear to so called non-linear. Then, when you have a complex system, variables can interact not linearly. They can multiply up exponentially.

Brazil is very late in this matter. Already the United States to stand with the New England Complex Systems Institute (NECSI), a partnership between various institutions, such as Massachusetts Institute of Technology (MIT), and the universities of Harvard and Brandeis, organized with the purpose to train human resources and do research and development activities on Engineering of complex systems. This year are conducting their eighth Congress of Complex Systems Engineering. The first was made in 1997.

Despite the delay and in the subject, some recent national initiatives, such as two national institutes of science and technology (NIST) of the Ministry of Science, Technology and Innovation (MCTI): the INCT complex systems and INCT math, which has projects in this area. There is also a working group at the Institute of Advanced Studies (IEA-USP) of São Carlos, who is articulating with international initiatives, and Institute for the Study of the Complexity (IEC).

The IEA USP-São Carlos, created in 2008, by professor Sérgio Mascarenhas together with professor of chemistry Institute of USP São Carlos Hamilton Brandão Varela of Albuquerque and the professor of the Institute of Physics Yvonne Primerano Mascarenhas has contributed to the development of research in this area in the country.

Once again, since when sponsored the creation of Materials Engineering at São Carlos and the Physics Department of Recife, or when, during a seminar at UnB, 35 years ago, the physical Sérgio Mascarenhas said: *"in underdeveloped countries, we must always be careful, because even when we have reason to say that everyone is wrong",* Sergio Mascarenhas is covered with reason.