Professor Derek Hitchins, CEng, PhD, MSc, FIET, FCMI, Wg.Cdr., RAF, Retd.,

INCOSE Pioneer

Systems Scientist & Systems Anthropologist

October 2023

semper integritas

So, What ***Is*** A ***System?***

Or is *not* a system? *Maybe not quite what we expect…*

Many of us, it seems, define the concept of "system." *Differently*. There may be as many definitions as pundits—perhaps *more*…

Some invoke metaphysics: *'Systems are unreal; it's all in the mind. It's where I choose to set the boundary…'* Many define 'system' to 'conform' to their particular discipline: anatomy, biology, cybernetics, engineering, psychology, systems engineering, systems thinking, etc; so may be in mutual disagreement, suggesting some, at least, may be 'off the mark…'

Yet despite this veritable plethora of 'system definitions' and 'exclusions,' it seems difficult to come up with a *universally acceptable* solution. *Could it be that* ***system*** *is not a "thing" to be so closely defined? And, does it really matter?*

"System" is a…***Paradigm: a World View underlying the theories and methodology of a particular scientific subject…***
Oxford Dictionary Particular Subject? *Systems Science.*

System represents ***Order*** in place of ***Entropy***…***Entropy***, disorder, is the universal destroyer. Of galaxies, stars and planets. Of constructions and civilizations. Of all material things. Of you and me. Eventually, all things must *decay into* ***disorder,*** heralding the inevitable *end of the Universe…*

Universally, although all ***systems,*** too, will decay, new ***systems*** are being created—new stars, new life, new concepts. new communities, new industries, new planetary explorers, etc., *so continuing the resistance to* ever-encroaching entropy.

Which leads to my *first:* not so much "definition" as…

..description of the 'System' Paradigm:—

<u>System</u>. A dent in the fabric of entropy……(1)

Which may be good physics, but a tad figurative in practice…

How about: "Order in the midst of disorder"? Or: "An oasis in a featureless desert"? Or even: "A coherent idea in a jumble of random thoughts?"

Which begs the question, is a system 'real,' or only in an observer's mind? If there is order, then its a system. Is the oasis real, before you see it—or, even if you never see it?

On a more prosaic tack, folks refer to:—

- a range of mountains as a **system**;
- a method for winning consistently at e.g. roulette;
- council procedures for allocating council houses;
- a method of government;
- military command & control;
- Pluto and its 5 moons;
- urban traffic management;
- automatic washing machine programs, powders & procedures, etc., etc.

All are referred to as **'systems.'** But, they don't seem to follow any obvious pattern. What do they have in common?

- They are all whole, i.e. 'in order,' by being complete
- They can all be seen to comprise interconnected, or interacting, parts, processes, procedures, notions, or things
- And they are all perceptibly complex…i.e., consisting of many different and connected parts yet, at the same time, whole/complete.

So to my second *Description of the 'System' Paradigm*:—

"System: a complex, organized whole of material or immaterial things"……(2)

"Whole" and "Organized" both imply order, so this 'definition' subsumes Definition (1).
Etymology. *System.* From the Greek *systēma:* "organized whole; a whole, compounded of parts."

Looking inside 'the whole,' at the many interconnected/interacting parts: these may be varied/diverse, and ***organized*** in different ways. According to the way things are ***organized*** within the whole, they may result in *different degrees of configuration* ***entropy.***

Put another way, there can be different degrees of "system-ness," according to the internal organization…So, ***a system may have an "optimum" configuration,*** corresponding to the lowest entropy/*greatest order*...

Which is important for manmade, sociotechnical and human activity systems/committees in particular, since–by definition– ***the lower the entropy, the greater the availability of a system's energy for conversion into work.*** *(Kelvin's Laws of Thermodynamics.)*

So to my third <u>*Description of the 'System' Paradigm*</u>*:*

"System: A set of complementary, interacting parts, with properties, capabilities and behaviors emerging both from the parts and their interactions to synthesize a complex, organized whole, body of material and/or immaterial things."……(3)

- ***Complementary***. Combining in such a way as to emphasize the qualities of each other or another…
- ***Interacting***; Acting so as to have an effect on each other
- ***Synthesize***. Combine a number of things into a coherent whole
- ***Complex***. Consisting of many different and connected parts
- ***Organized***. Well ordered, orderly, neat & tidy…
- ***Whole***. Entire, complete, aggregate, no missing parts…

Which, taken all together, is once again about reducing entropy—so affording potential for consequential benefits of more available energy with improved efficiency & effectiveness…

N.B. Any system is internally dynamic: all parts are functioning, interacting. Else, the whole is 'dormant,' inactive…

Note, in this "definition:" no *particular* pattern; no limits to numbers of things; nor to diversity/variety/type/category; nor size; color; shape; nature…indeed, no limits, demarcations, or ranges, of any kind, at all. The definition is not spe-

cific to any domain, situation, discipline, life-form, galaxy—but, OTOH, should be appropriate to all of these; and more… The "definition" also indicates what is *not* a system:—

- **Incomplete things:** a eunuch; an axeman without an axe; a piloted aircraft without the pilot; an automobile minus any part crucial to its mobility–propulsion, driver; etc.
- **A disarrangement/randomizing of material, or immaterial things;** the numbered ping-pong balls in a rotating drum being used for a draw…
- **A collection of unconnected/non-interacting things:** an unrehearsed, conductor-less orchestra; a bag of pool balls; a choir of soloists; an *ad hoc* rugby team…
- **Inactive things:** a quick-reaction fighter, sat on the runway, pilot *in situ,* engines and power off, static & silent, awaiting alert… = 'dormant.' Etc., etc.

In Definition (3), the terms 'complementary' and 'interacting' are significant. *First,* they contribute to creating order/reducing entropy by "correlating the parts," as in a completed jig-saw puzzle.

Second, complementary interacting parts are unlikely to occur by accident—they occur either by *design,* or *natural selection,* as in Nature: e.g. planetary systems; plants & animals; male & female in biological reproduction…

This second also has implications for systems engineering. Evidently, it is necessary to *design* systems that we wish

to create. In particular, to design for "complementary interaction;" else the solution may be far from optimal. Moreover, this complementary feature occurs throughout the system-in-design, with all parts dynamically complementing others…

Which requires, in turn, that the whole should be designed *as one system. (i.e. the Systems Approach.)* Not as separate parts to be then simply joined together, as much of the "complementary-interacting" would be missed…so entropy would be greater, less energy would be available for work, so efficiency and effectiveness would both reduce.

Similarly, when it comes time for *integration & test,* the whole should be brought together and tested *as one system. (Again, the Systems Approach).* Not progressively, part by part. Else, the finished whole will not match the systems design, entropy will increase, less energy available for work, reduced efficiency and effectiveness.

All of which justifies holism as a guiding principle of system methods, systems thinking, systems engineering and systems operations:—

Holism. *The theory that the parts of a whole are in intimate interconnection, such that things cannot exist independently of the whole, or cannot be understood without reference to the whole, which is thus regarded as greater than the sum of its parts. Oxford Dictionary*

So, does it matter if there are different definitions of 'system'? Definition (2), above, seems to cover most informal uses of the notion of system, and people at large seem to have an intuitive understanding of what a system is, or might be, in general terms. 'Experts' may decry the everyday use/abuse(?) of the term, but it has been in the English language since the AD1600s, and the population at large surely cannot be wrong in their common understanding.

Issues may arise, however, when scientists and creators use their particular notions of 'system' to further their own discipline, or create superlatives. And, there does appear to be a tendency to define 'system' so narrowly that the definition excludes many things that are, clearly, systems—on any reasonable basis.

One notable exclusion is of living things, particularly animals, and especially humans. Definition (3) would evidently include all 5 Kingdoms of Life: bacteria, protists, fungi, plants and animals…but some scientists and many engineers, for instance, do not accept that *a human is a system.* Despite a human's observable synthesis from some 12 or 13 organ systems (central nervous, digestive, cardiovascular, pulmonary, etc) to form a complex, organized whole, body of material things…

Moreover, many engineers exclude stars and planetary systems, including our own solar system. Yet our Sun fits definitions (1), (2) and (3), as does the whole solar system, not to mention the Milky Way, Pulsars, Black Holes, and the Universe…

From the foregoing, system methods, systems thinking, systems design, systems engineering & systems operations ***all eschew reductionist approaches***, which run counter to the fundamental *Systems Approach* of ***holistic synthesis.***

During the second half of the 20C, the Cold War years, ***Systems Engineering,*** holistic synthesis, was applied widely in:—

- defense and aerospace:–
- Apollo, Aegis, Star Wars,
- UK Air Defence,
- fighter aircraft design
- fighting ships design
- weapon systems,
- command & control,
- hospitals & airports,
- enterprises & businesses,
- industries, manufacturing
- emergency services,
- integrated transport,
- air traffic management,
- peace operations…
- international rescue
- disaster relief…

…all to their benefit, through innovation, management of complexity, re-organization, greater efficiency, and improved effectiveness in these ***sociotechnical systems…*** But, not so widely now, however…

First, there is a concerted move to invoke Cartesian **reduction**/decomposition within systems engineering, ***rejecting holistic synthesis,*** with the consequent potential for greater *complexity,* extended *timescales,* reduced *innovation* and increased *entropy,* so non-optimal, and prejudicial to efficiency,

effectiveness and performance in operation—i.e. *"less bangs per buck!"*

Second, and even more concerning, since *reduction & decomposition* are inapplicable to people, this contemporary *quasi-systems-engineering* is reluctant/unable to address ***human activity and socio-technical systems****—disregarding them as* ***systems*** *by virtue of their people content (i.e. by using a restrictive definition of 'system').*

For Systems Engineering, together, these two are unfortunate ***betrayals of both science and heritage****.*

Don Del October 2023