Professor Derek Hitchins,
CEng, PhD, MSc, FIET, FCMI, Wg.Cdr., RAF, Retired.,
INCOSE Pioneer
Systems Scientist & Systems Anthropologist
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sit vis vobiscum

Systems Engineer Essentials:
2. Systems Methodology!!

*What every **Systems Engineer** should understand…*

First, what does a Systems Engineer do? Well, that should be self-evident, surely—his discipline is Systems Engineering (Applied Systems Science), his rôle as a Systems Engineer is to create viable Systems Solutions to complex issues/problematic situations, with the Systems Approach as his watchword and employing the Systems Design Methodology.

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Systems engineering evolved and matured during the Cold War, when our, then, Soviet chums, took to creating ever newer, ever deadlier Threats against their

former allies from WWII. We would get ‘leaks’ of successive threats, which offered little about the Nature of said Threat. But that it was existential! Ho hum…

Could Systems Engineering (SE) find a way to counter this vague threat? Possibly. But *SE would have to evolve,* to create a counter against the *virtually unknown*…

1. First, then, came the notion of expressing the customer’s issue as a problem, rather than as any defined requirement: moreover, as a problem to be addressed in a *deliberately abstract way* in order to prevent and preclude *prejudice*.
2. Second, any solution to the customer’s problem was clearly going to be complex and sophisticated, in keeping with the morphing threat. Any weapon, aircraft, ship, etc., would become part of an overall offensive/defensive “barricade,” and would need, therefore to be both compatible and interoperable with many others. Performance *in Operational Environment* was crucial...
3. Third, since the solution to the customer’s problem might be almost anything, it would surely be inappropriate to conceive and design physical structure and hardware: there might not be any…The solution to the customer’s problem would necessarily have *purpose,* however, and would necessarily perform functions in pursuit of that purpose:—

- So, *instead of conceiving structures,* ***conceive functions***—many interacting, cooperating functions that together would create…
- …***synergy,*** leading to…
- …Solution system emergent properties, capabilities, behaviours, and…drive towards the realization of purpose.

These provisos became central themes in what came to be known as the "Systems Approach." By definition, a system was something suitably vague, yet precise: a ***paradigm***. I.e…

…a *complex, organized whole…*

of material and/or immaterial things

And it was that very ability to be "precise though vague" that was its power—something which many engineers found–and *still* find–difficult. The notion of 'system,' however, had a rigorous mathematical basis, as defined in Kelvin's First and Second Laws of Thermodynamics, where internal energy and entropy are measures of "system." And there is a host of implications in "organized…" And another host in "whole, complete…" And yet more in "open."

So, the answer to the customer's problem would be a "Solution System," initially at least, formless. But able to perform functions and exhibit properties in its operational environment, in the pursuance of some purpose—and, consequently, in the solving of the customer's problem or issue…

Systems Design would progressively clarify and give definition, identifying the many functions and their interrelationships, before organizing them into *interacting, complementary functional subsystems,* which could then be realized, underpinned and performed by physical entities—people/teams, enterprises, organizations, machines, buildings, orbiters, landers, rovers, transports, power supplies, etc., etc.

And…the people would be *an integral part* of the solution system, performing appropriate functions as part of the whole—not "integrated with the technology" through some unavoidable "human interface" afterthought.

And the so-called ***Systems Design Methodology,*** or simply ***Systems Methodology*** evolved as sequential phases, each with its own system method, broadly as follows:

- Problem scoping and exploration, including the Solution System future environment…
- Problem solving, leading to…
- Conceptual Remedial Solutions
- Operations Analysis (OA) of competing Conceptual Remedial Solutions
- Tradeoff between Conceptual Remedial Solutions: performance, viability, compatibility, sustainability, cost, etc.
- Preferred Concept of Operations (CONOPS)
- Functional Synthesis of Solution System(s)
    - Dynamic Modeling of Solution System ***interacting within its Operational Environment*** to validate and optimize functional design & compatibility…
- Emergence of Functional Architecture and Functional Subsystems
- Functional-to-Physical Mapping, leading to…
- Development of Functional-Physical structures into a Viable Solution System
- Matched Set of Requirement Specifications for whole Viable Solution System

1. The whole of the above procedural activities deliberately avoid *any* decomposition/Cartesian reduction, functional or physical, which would prevent interaction & complementation, so invalidating systems design optimization.

2. Starting with the problem, or problematic situation, enables the subsequent process to be one of synthesis *only*…

3. Employing synthesis *only* suggests that the solution system, in its operational environment, may be ***non-linear,*** with consequent opportunities for enhanced emergent properties: e.g. increased power density, efficiency and effectiveness…

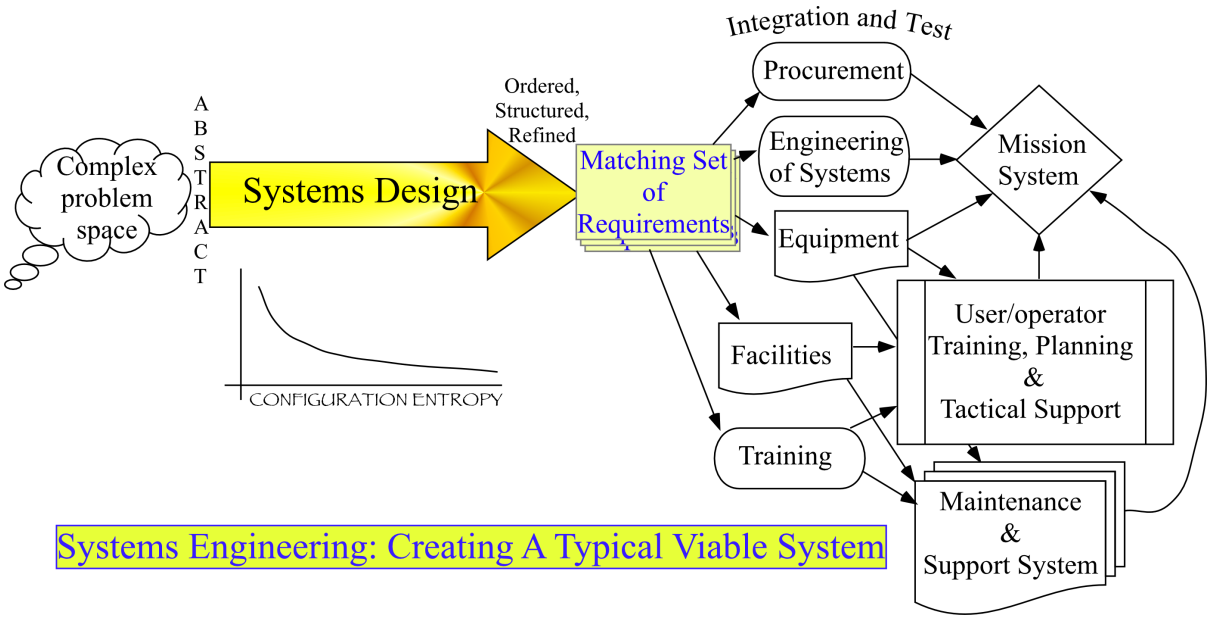
4. There is no mention of stakeholders, who would inevitably introduce prejudice into the proceedings. However, stakeholder *domain, context* and *environment* information may be useful during 'problem scoping.' Especially antipathetic stakeholder information.

The diagram presents the systems design methodology ('system of methods') as ***Systems Design***, in this case for some form of maintained and supported Mission System, which might conceivably be any of, for instance:

- an Antarctic submarine research vessel,
- a stratospheric transport system,
- a remotely-piloted fighter-interceptor cluster,
- an autopoietic manufacturing organization,
- a new specialist hospital for p.t.s.d. sufferers,
- a rehabilitating custodial centre,
- an international space rescue organization
- a "self-dispersing dust-cloud" at the L1 Lagrangian point to put a temporary brake on global warming
- Etc.

Systems Methodology invoked the skills of many disciplines, including–but not limited to–systems scientists, mathematicians, systems dynamics modelers, anthropologists, psychologists, behavioral scientists, ecologists, value engineers, operations

researchers, management scientists, cyberneticians, physicists, chemists, physical biologists, archeologists, etc., etc. All were considered to be "systems engineering…"



Of course, Systems Engineering as a powerful problem-solving capability is not confined to the conception and creation of Mission Systems, no matter how 'far out'. It is limited only by the imagination, capability and domain knowledge of its ***Systems Engineers.***

And, for those of you who disagree with all of the above 'nonsense? I'm not surprised…but you are ***wrong! Again!***

Don Del *March 2024*