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Veritas me dirige.

So—Who's taking the *SA & SD* out of *SE? And* ***Why?***

SA is the Systems Approach, of course… It is—*should be*—at the very heart of Systems Engineering (SE), and arguably why *Systems* Engineering is so-called…

SD is Systems Design, which stems from the SA…and, *inter alia,* designs the operational system (a.k.a. the Solution System) *in its operational environment!*

Who cares? Well, it's to do with Open Systems, Holism and all that… Open Systems exchange Energy, Information and Material with their environment and *adapt to the exchange.* And, it seems, all *real world* systems *are* Open—Natural *and* Man-made. That's a big deal. **So, you *should* care!**

And the Systems Approach has been adopted by many disciplines beside SE. Here's what a psychologist had to say:

> *"We used to think of personality as a fixed entity within the mind. Then we realized that personality could be*

affected by interacting with other parts of the mind. Then we realized that personality could have an effect on the health of the whole body—and that the health of the whole body could affect the personality, too. And we came to realize that personality could be affected by interacting with other personalities…"

So, the Systems Approach seeks to understand the part *only in the context of the whole, interacting with, and adapting to, its environment.*

Compare the *engineer's* procedure with the ***systems approach,*** attempting to explain some complicated entity…an automobile, say…

Engineer Procedure	**Systems Approach**
1. Decompose that which is to be explained/understood *(Decomposition)*	1. Identify a containing system of which the thing to be explained is part
2. Explain the behavior or properties of the contained parts separately	2. Explain the behavior or properties of the containing whole
3. Aggregate these explanations into an explanation of the whole *(Synthesis)*	3. Explain the behavior of the thing to be explained in terms of its *roles* and *functions* within its containing whole *(Synthesis)*

Engineers' Procedure	*Systems Approach*
Car consists of… • *Chassis & Suspension* • *Power Unit* • *Transmission* • *Steering* • *Controls & Displays* • *Furniture & Body-work, etc.*	*• Part of wider family transport system—to accommodate "typical family: parents +2/3 children"* *• Easy to control, reverse, park, etc., by any family member, teens and oldies; secure from stealing. Zero interference with other road users* *• Ultra safe in event of collision: travel between refueling c. 300miles: reliable, inexpensive to service & repair* *• Non polluting: minimal damage to environment, others in case of accident. Recyclable. Etc., etc.*

Looking outwards into the containing system(s) in this fashion leads to improved features, smarter designs, and customer appeal.

And is, of course, *how to formulate requirements!!* Notice how relevant stakeholders are *automatically* included using the systems approach—no need for separate, possibly dubious –and potentially biased–stakeholder input. And, leads on to: what *kind* of suspension, what *style* of furniture and body-

work, how far to travel on one fuel load, preferred fuel for minimal pollution, etc., etc. All these, and many, many more emerge simply from taking the Systems Approach.

Try it for yourself—you'll be amazed at how simple it is to do, once you disabuse yourself of the Cartesian Reduction edict, with which we have all been inculcated since birth.

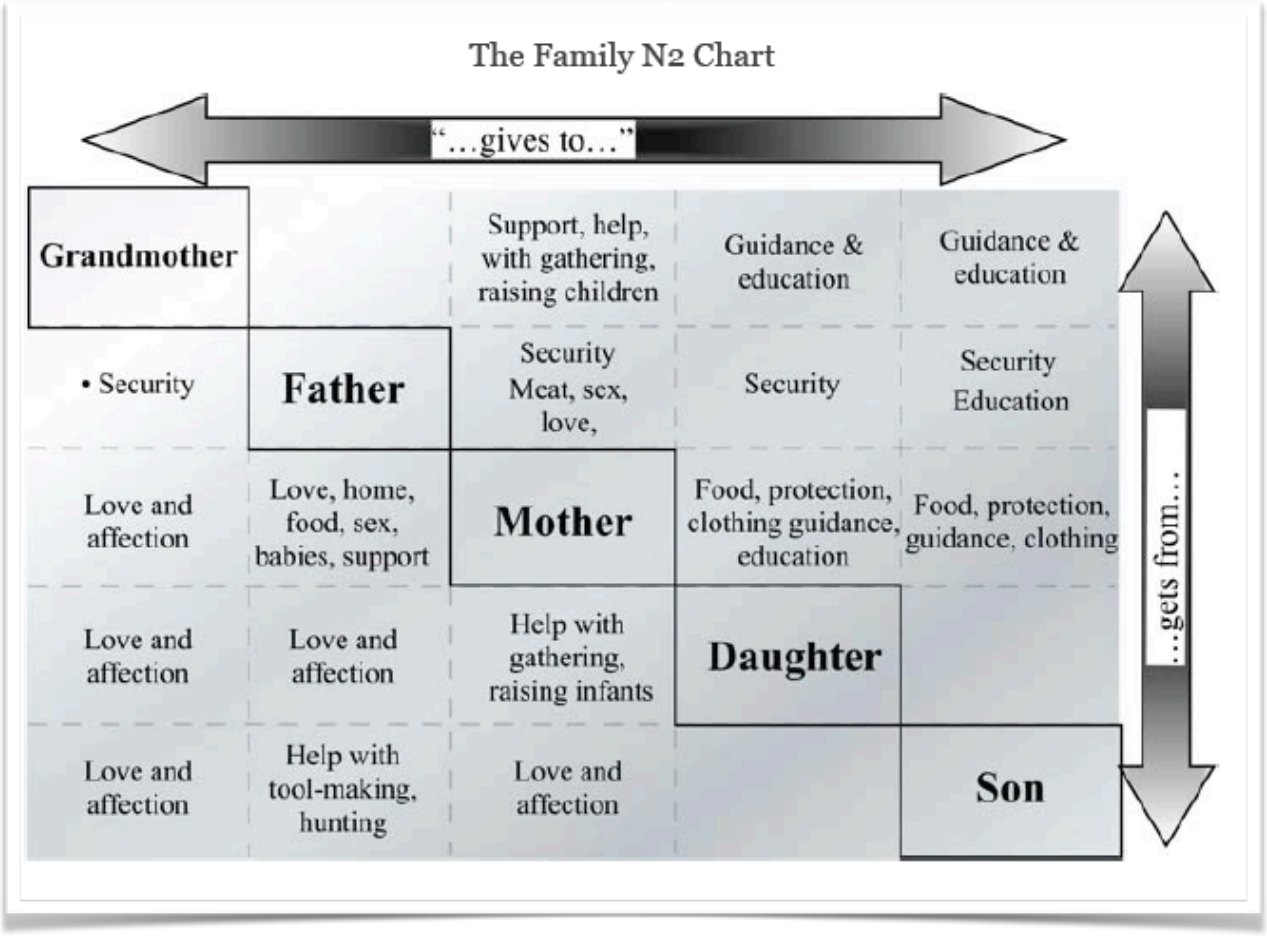
Let's look at another, quite different example:—

Consider a typical Hunter-gatherer family - the building block of clan/tribe/society - *After all, we're still instinctive Hunter-gatherers under the skin. Right?*[p]

The Containing System is the ***nuclear family:—***

- a social unit for procreating, nurturing, rearing, protecting and maturing successive generations of stable, monogamous humans in a continuous sequence of nuclear families…
- The N2 chart below illustrates the complementary rôles and functions of family members. No Cartesian *reduction*, no *decomposition*, no *analysis*…just ***synthesis***
- The whole is a complex, organized whole of material and immaterial things, i.e., *an archetypal human activity system*

The Hunter-Gatherer Family is Emergent. The various members coalesce into a single, self-sufficient, stable & survivable *unit* with the ability, along with others, to defend and reproduce itself. In a turbulent and dangerous environment. To which it can, and will adapt…



Entities are on the leading diagonals. Other cells represent interfaces. Outputs are on the horizontal, Inputs on the vertical. So, Grandmother gives support and help to Mother with gathering, and with raising the children. Daughter gives Love and affection to Father. Etc. The empty cells tell a story, too…

Moreover, the *unit* exhibits behavior—as we know, not all families behave in the same way. And, the behavior of the individuals in the family will evolve and adapt—each family

member is, after all, an open system (*sic),* so will exchange energy, information and material with other members and will adapt to the interchange…all within the context of the whole family.

So, the family unit is *internally dynamic,* with members continually interchanging with, and adapting to, each other… ***Which segues—rather conveniently—into the concept of Systems Engineering.***

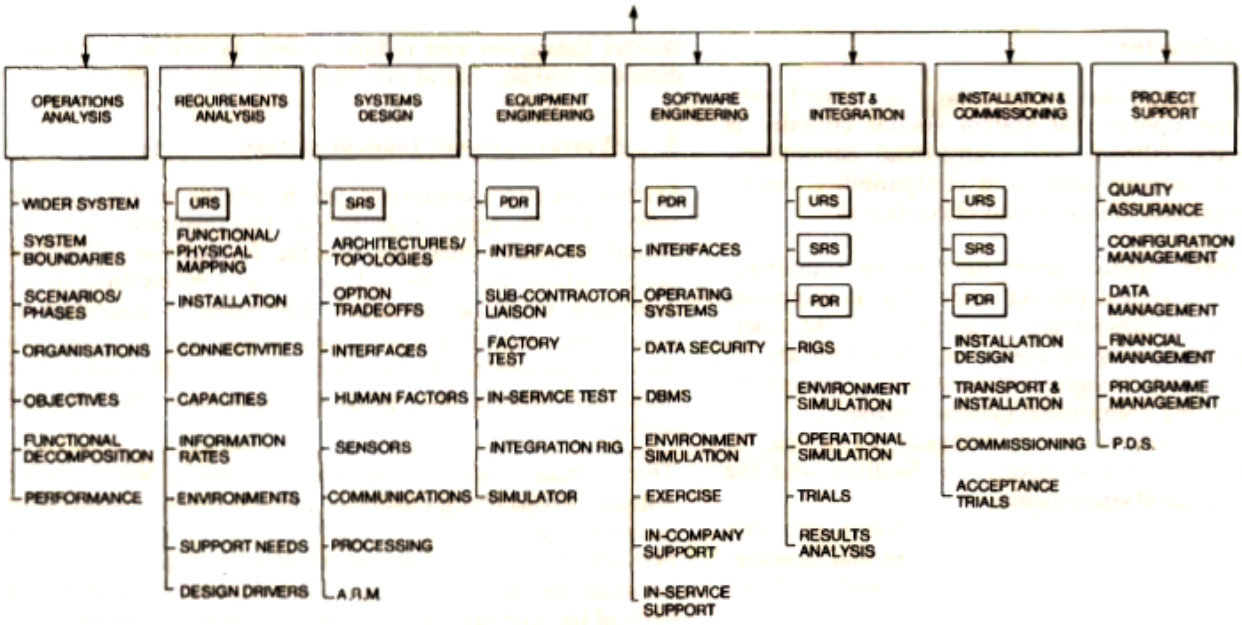
Systems Engineering seeks to create *purposeful systems,* i.e. systems with a clear purpose to achieve a goal/objective, solve a problem, or resolve some issue. Moreover, *viable* systems that *sustain* themselves, even in challenging environments…

As befits the concept of Purpose, ***Systems Engineering is functionalist:*** i.e., it identifies *functions* which, taken together, will enable some future system to pursue a mission, to achieve a goal, to perform well, to solve a problem. It brings complementary *functions* together, to cooperate, to synergize…

And, since humans can readily perform *functions,* the overall system can consist of: cooperative, complementary

humans; or, of *functions* performed by people and technology together; or, by technology alone. Moreover, systems being *organized* and *optimized* with "minimal configuration entropy," offer maximum efficiency…*with optimum Performance!*

Systems Engineering Methodology from *"Managing Systems Creation,"* D.K. Hitchins. IEE Proceedings, Vol. 133, Pt.A, No.6, September 1986



URS=User Requirement Spec. PDR=Performance and Design Requirement.
SRS=Systems Requirement Spec. ARM=Availability, Reliability, Maintainability.
DBMS=Database Management System PDS=Post Design Services

The chart[1] shows typical Systems Engineering phased activities of the '80s, with each phase marked by the completion of its relevant specification, as shown. Note Functional Decomposition in the Operations Analysis column. At that time, *cre-*

[1] From:—https://systems.hitchins.net/se-evolution/managing-systems-creation.pdf

ating advanced sociotechnical systems was the norm. Today, it is "too difficult," and methodologies such as that depicted above seem to, somehow, totally escape contemporary research into SE. Now, how could that be? Accidental? Surely not—there are whole libraries dedicated to the former, highly-capable, systems engineering…all rather difficult to miss.

e.g. Wiley Series in ***Systems Engineering and Management,***
e.g. International Federation for Systems Research's ***International Series on Systems Science and Engineering.***
To name but two…

Any Solution System, to be Purposeful and, at the same time Viable, requires *(inter alia)* ***Function Management,*** comprising three interlocking aspects, as shown in the figure below:

- ***Mission Management,*** to gather information, continually, about the environment in which the Solution System is/will be operating, including hazards, threats, openings and opportunities; to use that information to (re-)formulate strategies and plans to manage the perceived risks, and to increase prospects of successful outcomes; to execute the plans, in cooperation with others in the environment
- ***Resource Management,*** to anticipate and provide all resources required throughout the mission, both to sustain the mission and to maintain viability,

- ***Viability Management,*** to maintain the Solution System in the face of threats to its successful operation and hence to its achievement of Purpose. Viability can be considered under a number of headings:—
  - **Survivability**, or durability, which in turn presents aspects of : Avoidance of Detection; Self-Defense; Damage Tolerance; Self-repair; Reconfiguration; Security
  - **Maintenance**: detection, location, repair/excision/replacement/ reconfiguration, waste disposal
  - **Evolution**: adaptation of performance/behavior to longer term changes in environment
  - **Synergy**: Cooperation, coordination, complementation, concinnity, control – of and between the subsystems/parts, creating emergence
  - **Homeostasis**: Dynamic equilibrium between the interacting subsystems, maintaining a relatively stable internal environment

In short:—

• ***Viability Management*** provides for continuing operation in the face of threats, failures and defects.

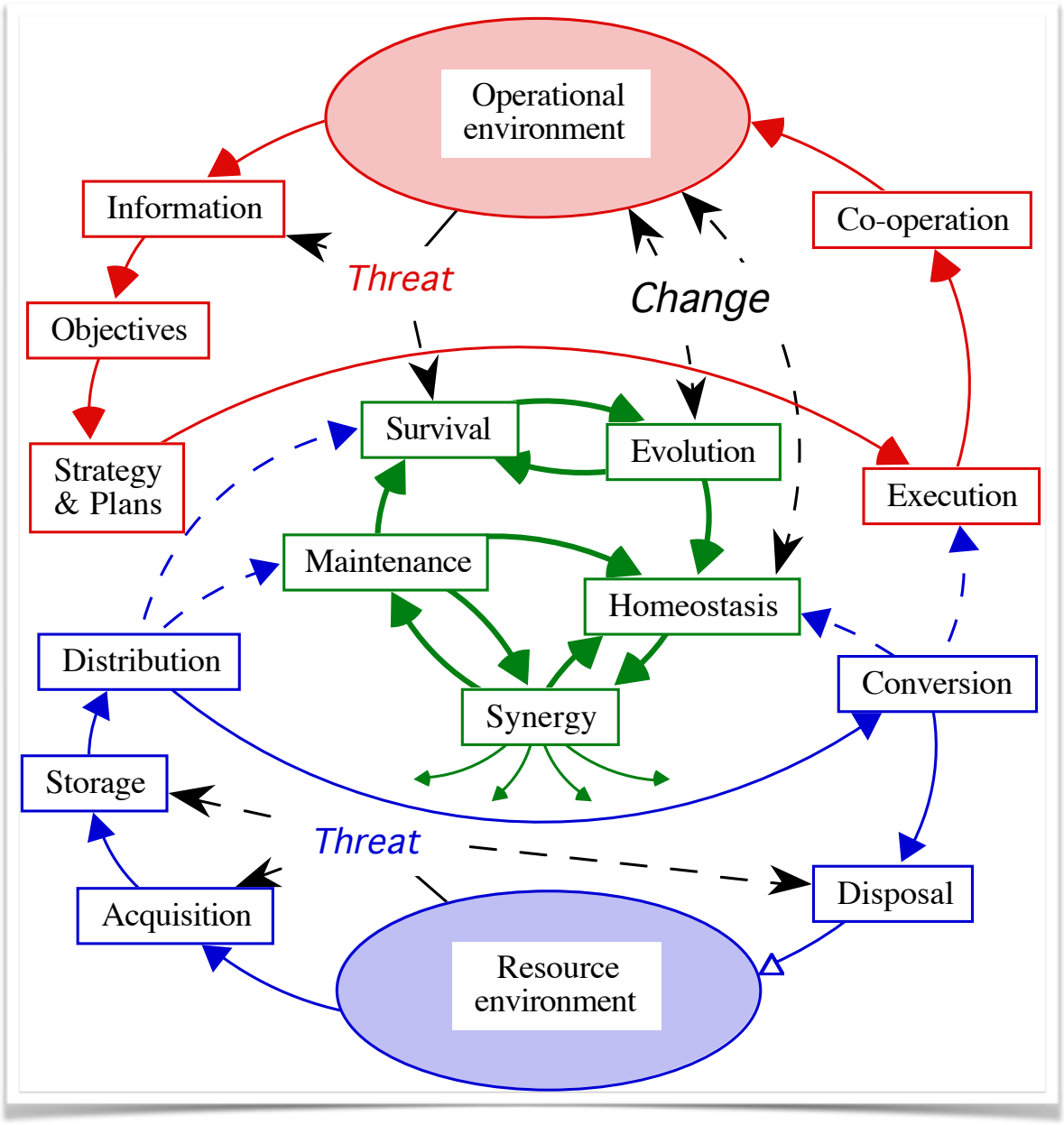
• ***Resource Management*** provides the necessary resources to sustain the Mission, both physically and functionally. And

• ***Mission Management,*** uh, well, it manages the mission to achieve its Goal, Purpose, or Objectives.

{And a Mission could be anything. *Going to the shops; breaking into new markets;"busting dams" in WWII; creating a viable operating base on the far-side of the Moon; designing a 'mixed' civil/military air traffic management system; integrating a city's transport systems; resisting global warming; etc; etc.*}

Part of:–Hitchins Viable Systems Model

–Function Management



Mission Management shown in RED. Resource Management shown in BLUE.
Viability Management shown in GREEN

From the foregoing, which is *context independent,* you can see the roots of ***Systems Design.*** First, establish domain and context: Operational and Resource environments, others in those environment, risks, threats, vulnerabilities, openings,

etc. Next, establish Purpose, Objectives, what is to be achieved, what problem to be solved, etc.

Then comes the Mission, how the Objectives are to be achieved. And there may be several different ways in which any Mission might be prosecuted, each with its own set of risks, costs, resource needs, and prospects of success, so a potential subject for, e.g., systems dynamics modeling, etc., to explore, evaluate and compare…And, once the preferred mission approach is established, the rest follows…

And, already, you can see ***the fundamental differences*** between systems engineering and engineering…

Engineering employs *decomposition* to identify the physical parts required, paying little heed to the future operational environment. And, of course, it is not possible to decompose a person. Engineering has a real problem with people being part of the overall system—*"no transfer function for a human."* People become adjuncts… *outside of the system…*

So, for engineering, sociotechnical systems, become 'inconceivable…' ***Moreover, and vitally significant, engineering creates only products & artifacts, while***

***systems engineering creates viable, autonomous, operational solution systems*…**

If Systems Engineering is functionalist/works with functions, how does anything physical get made**?** The many and various functions are organized into **functionally-bound clusters—**functional *architecture*. And, the functional architecture is mapped on to a physical architecture/substrate, formed of people and/or technology to perform the functions.

Functionally-bound clusters–*open functional subsystems*–will exchange energy, information and material with each other, such that the whole will be dynamically interactive in operation. *Exactly like the members of the Hunter-gatherer Family above.* Similarly, the whole will also be interacting with, and adapting to, its dynamically-changing operational and resource environments…

Now—shock-horror!—it appears that some contemporary versions of *so-called* "Systems Engineering" do *not* take the Systems Approach. Neither do they 'bother with' Systems Design. They do *not* consider that systems are Open. They expect functional and phys-

ical boundaries to correspond. They employ decomposition/ Cartesian reduction willy-nilly. They are, in short, still living in a passé mechanistic world, and not in a contemporary functionalist systems world.

And their tools and models are similarly comprised. SysML decomposes any "system" to 'describe' it in detail. So, presumably, as an offshoot of SysML, does MBSE.

SysML and MBSE may be appropriate for some post-systems-design *manufacturing phase* (if any) of Systems Engineering, but not, as presently configured, for the creative concept and systems design phases. Perhaps that will come…

All of which leaves the original question hanging:—

Is the Systems Approach fundamental to Systems Engineering…or not? And, it has to be said: Systems Engineering *without* the Systems Approach: therefore, *without* regard for Open Systems; *without* functional Systems Design; and, *without* the synthesis of functional architectures to optimize performance; is *comprehensively castrated!* It ***fails to create an operational solution system.*** Sorry, but it's just ***not*** Systems Engineering… it really is ***not even close…***

Hang on! You can't just dismiss it like that! So, what is it, then? What's left when SA & SD are removed?

Levels of Integration: Man Made Systems

Level	*Biology/ anatomy*	*Category*	*Descriptor*	*Activity*
8	Ecosystem	Organization/ Industry.	System	Autonomous Systems Integration
7	Community	Company/ Enterprise/ Business	System	Viable/Autonomous System Integration
6	Population	Group/Team/ Section	Subsystem**	
5	Organism	Platform	Autonomous /Viable System	
4	Organ System	Assembly	System*	System/Artefact Integration, *presumes* human element in synthesizing viable/autonomous system
3	Organ	Subassembly	Subsystem**	
2	Tissue	Composite	Artefact	Engineering
1	Cell	Component	Artefact	Engineering

* Part of a sociotechnical system or subsystem—with human participation
** Interdependent part of viable/autonomous system. Not viable on its own.

Mmm…The table classifies both natural and man-made systems by increasing complexity with level:

A. You can see the familiar ***Levels of Organization*** from school biology/anatomy at left. *'Many cells make a tissue; many tissues make an organ; many organs make an organ system; many organ systems make an organism…'* (Worm, honeybee, crow, human, etc.)

B. The centre column presents the corresponding ***Levels of Integration*** for *man-made* systems, going from Component at Level 1, to Organization/Industry at Level 8. Level 5, Organism ≡≡ Platform, is seen as the *pivot of correspondence.* An organism (e.g. human) corresponds with a platform (automobile, ship, plane, etc). Each may be both viable and autonomous…
C. The right-hand column in the Table then shows *the corresponding nature of the activity. So, creating an artifact would be an engineering activity. Creating an Ecosystem would be autonomous (self-organizing) systems integration…*

Repeating the original question:

What's left when the Systems Approach is removed from Systems Engineering?

(Referring to the Table…at bottom right.)

"Artifact engineering. So, just *straight engineering,* sans systems…Excludes *all socio-technical systems*…Yet, weirdly, seen by <u>some</u> as the only 'true' Systems Engineering…"

Presumably, those would be the ones who took the SA & SD out of SE in the first place, and did not pause to count the cost!!

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Shouldn't we, perhaps, stop promoting our present pastiche of 'systems engineering'
(≡'creating systems')…
..which patently <u>fails</u> to "create systems!"

<u>..and…</u>

Instead, restore the Systems Approach, re-constitute a <u>new, up-to-date</u> Systems Design for all our futures, and restore the basic principles of Systems Engineering viz: <u>holism, synthesis & organicism.</u>

Then Systems Engineering, the real deal, can address the URGENT problems and issues of today—and tomorrow!
Time is pressing…