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Systems Engineering

and the

Viable Systems Model

I read an article recently about "systems of systems"… Apparently, there could be lot's of things 'in'—but *not part of*—a SoS besides the constituent interacting systems. Which was problematic. Curious…

F'rinstance, if you considered a car as the SoS, then the constituent systems might include propulsion, transmission, steering, etc., i.e. all the parts actively involved in vehicle operation. But, what about things like the spare tyre, the jack,

tools, etc? They weren't involved in the operation, weren't interacting, so surely shouldn't be considered part of the SoS?

Now, that feels intuitively wrong, doesn't it? Carrying spares and tools in case of problems is simple common sense… And, if we think about, say, a military aircraft, ship or tank, then we know that they have all kinds of facilities on board, "just in case:" reversionary modes, self tests, built-in test equipment (BITE), standby equipments, even spare LRUs that the crew can swop for a "dodgy" one… None of these is integral to the "operational system"—whatever that might be. They are there "just in case…"

And this set me to wondering if contemporary versions of *"System of Systems Engineering"* have a problem!

The *original* systems engineering concerned itself with solving the customer's problem, which meant conceiving, designing, synthesizing, commissioning and supporting a ***viable solution…***

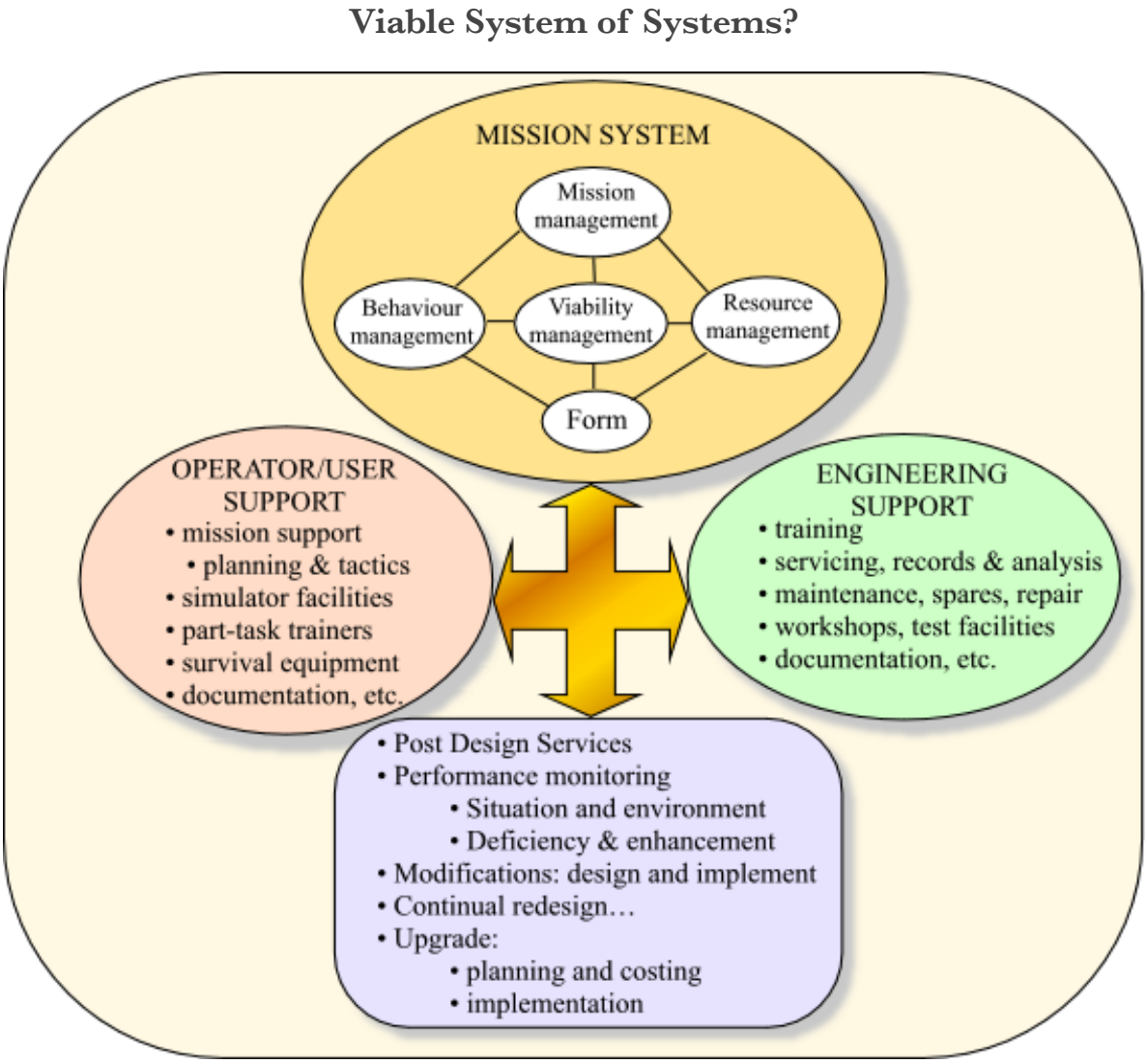
- Viability is the ability of a thing (a living organism, an artificial system, an idea, etc.) to maintain itself or recover its potentialities
- Whence, ***Viable System***…
- A ***Viable Systems Model*** (VSM) is a scientific model of the organization of a *viable* or *autonomous* system

Of course, the customer wants, and *needs,* a viable system. Who would buy a new car/tank/washing machine/airliner if there was no servicing support & maintenance facilities…no trained technicians, no manuals, no anything…?

Further, classic systems engineering (SE) operated from system concept to system replacement or, to use the then-popular expression, "from spurt to dirt!" So, whole of life, very much including the operational phases, continual re-design-thru-life, mid-life updates, variants, refits, and eventual replacement…all is, or perhaps really *should* be, SE.

Unfortunately, Engineering of Systems, the contemporary approach to systems (of systems) engineering, appears to fall a tad short of the classic, original SE. At least, according to the article I read on System of Systems…

So, what's up today? Are we no longer designing and operating *viable* systems? Are we simply engineering products to meet the customer's requirements? That would be no bad thing except–of course, they need not be *viable* solutions… Mmm… We used to do things so much better!



Typical Turnkey Systems Solution provided by the contractor. The Mission System was an episodic Viable System. The whole was a Thru-Life, Autonomous Organization

The diagram above represents a turnkey solution back in the day, with the contractor supplying not only the viable Mission

System the customer wanted, but all of the facilities, training and documentation needed to operate and maintain the Mission System thru life… The customer expected to walk in on day one, "turn the key," and everything should work—in principle, at least… Practice might be something else…but, that was real life—every new solution needs a shakedown!

Reference Models are used widely in the creative arts and sciences. A reference model represents the 'end product' so that the designer of a new 'thing' may see from what it might be constituted, what parts, how they might be organized, arranged, interconnected, etc., and how it should fit into its environment. The reference model could be simply a diagram with a list of parts, or a series of pictures, a cardboard model, or even an artists impression of the 'yet-to-be-made' thing in its future environment.

Back in 1992, I came up with the idea of a reference model for a system, any system. As you do… And, because this was to be for *any* system, I called it: The Generic Reference Model (GRM), and published it in a book, *Putting Systems To Work* (Ref. A). Which was a bit bold, you might

say. How can you have a GRM for something as vague and imprecise as *any system,* where a system might be:

> *"*An open set of complementary, interacting parts with properties, capabilities and behaviors emerging from the parts and from their interactions to synthesize…
>
> *'…a complex organized whole/body*
>
> *of*
>
> *material and/or immaterial things…'"*

You could use the whole of that paragraph as the definition of any system, or just the last, italicized part. So, a set of ideas could be a system. A well-written book could be a system. A team could be a system. And, an automobile could be a system, too…given a driver to drive it. (Else it's an artifact!)

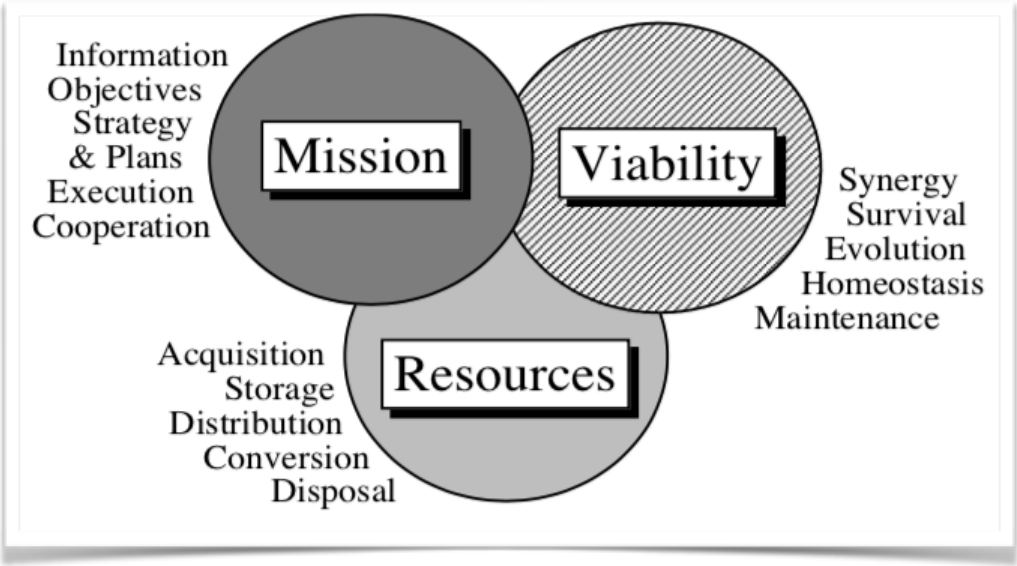
Which segues conveniently to the constituents of a Generic Reference Model for any system:

- All systems will have ***form***, or existence.
- Many systems may perform ***functions***
- Some systems may exhibit ***behavior***.

Back in 1992, I had yet to undertake the research necessary to formulate a Behavior Model, which emerged only later (Reference B). Still, the GRM (Form) Model and, *particularly the GRM (Function) Model,* were to prove useful in the interim.

And here is the Function Model in its original, 1992 form…

The Generic Reference (Function) Model Ref. A



Mission, Viability & Resource Management, each a member of a Necessary & Sufficient Set, can be elaborated into further N&S Sets…

Note, particularly the Viability element, with its constituents. These form a N&S set derived from assessing the external and internal *threats* to viability. Leading to the Viability acronym S-MESH (which may lack a certain *je ne sais quoi? Sorry…)*:

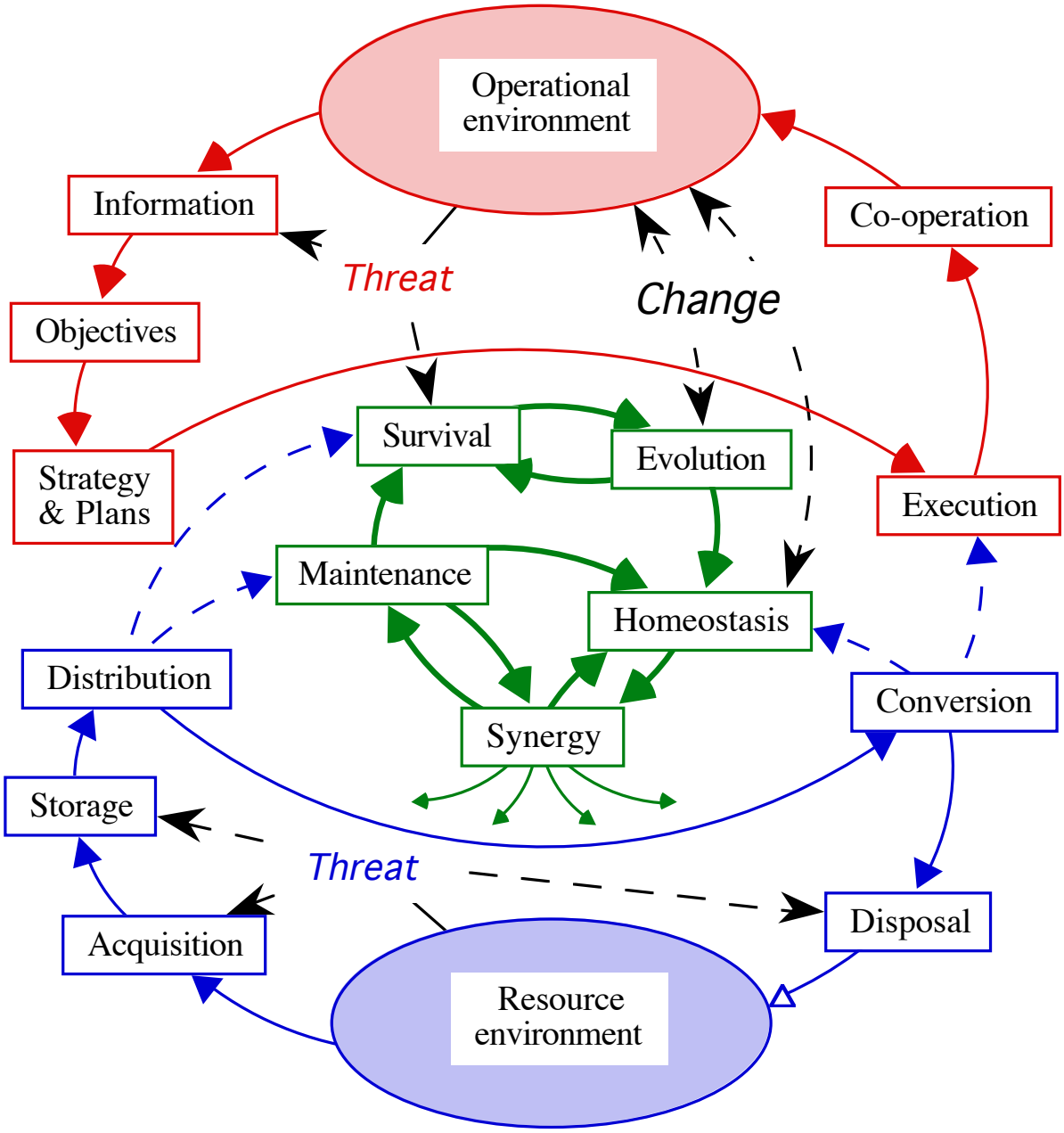
- ***S****ynergy*–all parts operating in harmony ‘to create a combined effect greater than the sum of their separate effects:’
    - All parts cooperating, behaving and performing together as a single entity, an integrated organized whole.
- ***M****aintenance*-dealing with internal threats
    - Detect
    - Locate, Isolate, Suppress
    - Repair, Excise & Replace
    - Restore prior potentiality: Redundancy, Back-ups, Reversionary Modes of Operation
    - Self-healing
- ***E****volution*–change in accord with changing environment
    - Adapt to changing Environment
    - Enhance/Re-optimize Performance in changing situation/ circumstances
- *Survival*
    - Avoidance of Detection
    - Self-Defense
    - Damage Tolerance
    - Damage Control & Repair, Reversion, Backup, Reconstruction
    - Self-healing
- ***H****omeostasis*–maintain dynamic equilibrium and internal environment to facilitate operations.

S-MESH is exemplified in the Causal Loop Model (CLM) version of the Generic Reference (Function) Model which, as it turns out, serves as (the basis for) an effective ***Viable Systems Model*** for any system. But, what is the model concept, how does it work, how can it be used?

Referring to the model, at the top is an Operational Environment, within which the mission is being pursued. Following the red arrowed lines, Mission Management ***senses/gathers/receives Information*** from the Operational Environment, ***sets/resets Objectives*** according to that information, ***re-formulates Strategy and Plans*** to achieve those objectives, ***Executes*** the plan and ***Cooperates*** with others as required in pursuit of the mission into the Operational Environment. These activities change the Operational Environment, so necessitating a continuing cycle…

At the bottom of the model is a Resource Environment. Following the blue-arrowed lines, all that can be done with resources is to: ***Acquire*** them; ***Store*** them; ***Distribute*** them; ***Convert*** them to whatever form is needed to make use of them; and, ***Dispose*** of any surplus or waste back into the Resource Environment.

Hitchins Viable Systems Model (Ref B)



Upper Red indicates the Mission Management Model.
Lower Blue indicates the Resource Management Model.
Central Green indicates the Viability Management Model.
Not shown is the continual flux of energy, information and material passing vertically through the open system model

At centre of the model can be seen the green-arrowed lines of S-MESH, the viability features. These refer particularly to the

platform or baseline (e.g. a craft, a person, a family, a worm, a team, a business, an organization…) upon which the Mission is being mounted, and the Resources-for-the-Mission managed. S-MESH features maintain the capabilities of the whole, so they refer particularly to the more physical elements of the whole, those that *enable* Mission and Resource Management. Also shown are Threats at various junctures, and Change which is endemic…

So, returning momentarily to the automobile from the beginning, we seem to have little interest in the "constituent systems," etc. That's engineering, not systems engineering, which—like the VSM—looks at the whole. So, Mission-, Resource-, & Viability-Management are not subsystems, but are *Systems of the Whole*….and *that's* Systems Engineering!

Instead, we might look at the design and operation of some potential solution, using the VSM as a checklist, design template and guide to completeness, etc. For example, under the Survival heading, there may be a perceived need (according to Mission) for Avoidance of Detection. This could require, say, hiding, camouflage, night-operations, thermal

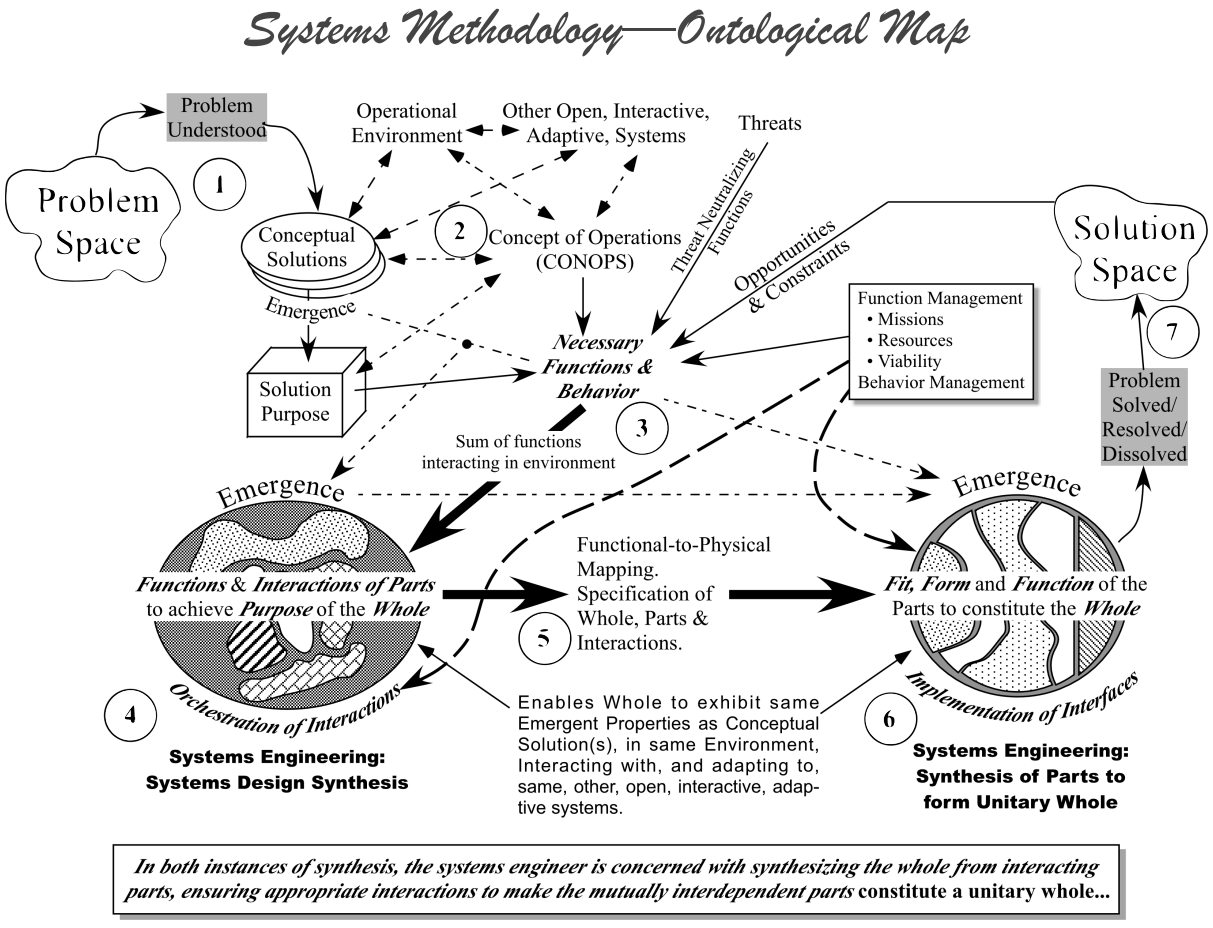
sensors, terrain screening to avoid enemy radar, or silent running—all according to situation and context. So, the VSM stimulates *design* choices to facilitate *tactical* and *strategic* options.

Also under Survival is Self-Defense, which prompts the System Designer to consider the Threat facing the Mission System. So, if the Threat is rain, self-defense might suggest an umbrella. If the Threat is more serious then self-defense might suggest armor, a defensive weapon, an attack weapon (attack often being the best method of defense), or circumventing…

Often the potential counter to some Threat brings its own baggage. So, armor can be heavy, potentially hampering as well as protecting, prompting a more fundamental all round redesign. (As with knights of old who, wearing heavy armor, had to ride on big, heavy horses—so, not so fast, not so maneuverable. Same issue with today's helicopter gunships…)

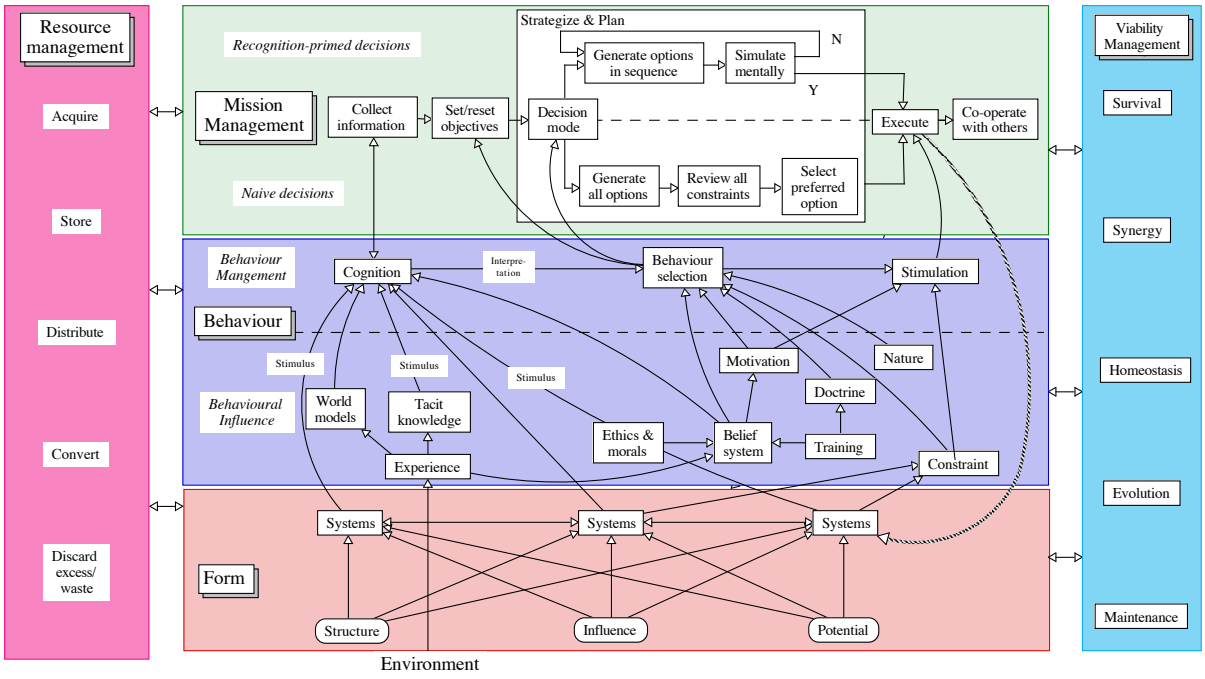
Similarly, Design for Maintenance, can significantly affect design and reliability. Indeed, every aspect of Viability Management can have a profound effect on what, otherwise, might look like a simple, straightforward design solution. But —a *vulnerable* one…

Using the VSM during the design stages also potentially enables the realization of emergent properties, capabilities and behaviors… which is a contentious claim, particularly among those who do not recognize emergence. Using the VSM as a template, it is possible in principle to *synthesize* a complete viable whole-system 'design-in-operation,' by following around the Mission Management and the Resource management loops, and identifying the means by which the various loop elements are to be achieved and integrated.



From Problem Space to Solution Space, incorporating Systems Design

Hitchins-VSM, layered: The Viable Solution System



Shows Behavior Management and Form Management in Layered form, plus principal interconnections between layers…

To pursue further any interest you might have in promoting viability, design synthesis, emergence, and so deriving 'more bangs per buck' from the eventual, viable mission system, please see: Reference B, a YouTube video explaining Hitchins-VSM (including the GR(Behavior) Model); and, References C & D, both (library) books for the more discerning, where the bases for Hitchins-VSM are to be found, under the heading:—

Generic Reference Model.

References:

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