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SM2: Exploring the Solution Space

Nothing puzzles me more than time and space; and yet, nothing troubles me less, as I never think about them

Charles Lamb, 1775–1834

Introduction

At the end of Chapter 7, we saw that the application of methods such as Checkland's SSM and Hitchins' RSM could help to organize efforts to explore issues and problems. RSM, in particular, presented one or more so-called remedial systems solutions at the end of the process, echoing medical diagnosis of organic dysfunctions. In keeping with the medical analogy, it should be remembered that there may be no solution to some problems, and that it is entirely possible to misdiagnose, especially where there is insufficient hard data and information to go on. Like any other method, SSM and RSM obey the 'garbage in, garbage out' dictum — except, of course, that RSM will reject as inappropriate any remedial solution system concept that fails to neutralize all of the original problem symptoms. This 'decisive test' is designed to prevent either misdiagnoses, or diagnoses that address only part of the whole problem, from being further implemented.

Generating a remedial system solution concept may be necessary, but it is far from sufficient. If the potential remedy is to become a real-world solution, then the remedy will have to work within real-world constraints, which may be physical, temporal, cultural, financial, etc. Bringing a conceptual system solution together with a representation of the solution space in which the solution must be viable and operational is the first step towards molding the remedial system solution concept into a real solution, resolution or dissolution to or of the original problem.

Approach

The approach is outlined in Figure 8.1, a behavior diagram that follows on in sequence from Figure 7.5 on page 199; note the input, top left, of 'remedial solution system(s)' was also the

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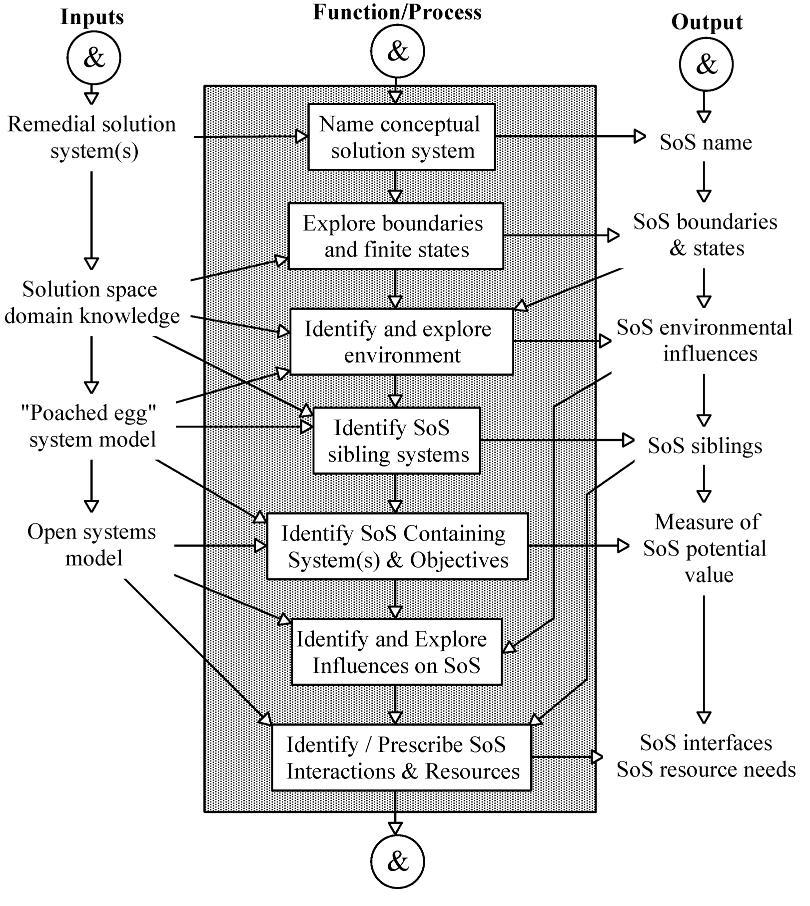

Figure 8.1 Behavior diagram — exploring solution space constraints. (SoS is 'solution system,' which is conceptual only at this early stage.)

output shown on the previous figure. The first step is to name the conceptual solution system: this is more important than it may appear; having the right name for a potential solution system gives it identity and substance in the minds of those looking for a solution. Conversely, giving it a poor, or inappropriate, name can damage the fledgling's prospects of being appreciated and realized.

Boundaries and finite states

The process of exploring the solution space is conducted methodically, first by looking for boundaries and any finite states that the conceptual solution system is likely to exist within, or may be required to observe: real-world systems are generally perceived as existing within clear boundaries, and they may also operate within a variety of finite states.

For instance, a nuclear power station will be well bounded, and may have strict limits place upon where it may be sited: it may also function in a number of different states, or operational modes, including an offline test mode, a standby mode, a backup mode, a work-up mode, a full power generation mode, a routine servicing mode, an emergency close-down mode, and possible several more. These boundaries and states are not inherent to nuclear power generation; rather, various administrative and regulatory features impose them in the solution space.

Similarly, a proposed new radar system may be required to have a number of different operating modes, including maintenance, standby, test, low transmission power (to minimize interference), high power (to overcome jamming interference), etc., all of which may be imposed by the solution space, and none of which is apparent from the conceptual solution of 'new radar system.'

Sometimes, of course, boundaries are simple, physical boundaries, as when three crewmen and their equipment have to fit within an oddly shaped capsule; when an avionics system has to fit within a limited aircraft hatch; or, a manufacturing process has to fit within a five cubic meter space. . . . Then again, a range of mountains, or a river, may bound a floral and faunal site. Motorways and similar highways may create unique ecosystems, in which rare species may thrive without interference from man, who rarely if ever visits the areas bounded by the dual highways. Or, a boundary could be associated with a culture, a moment of inertia, or whatever. The objective of the activity is to identify limits to the solution system that will be imposed by the solution space.

Environments, influences and interactions

Next in the sequence from Figure 8.1 comes 'identify and explore environment.' Simplistically, environment may be thought of as that which pervades the boundary in which the solution system will exist. The environment may affect the manner in which the various parts of the solution system interact to cooperate and coordinate their activities, and in so doing may affect synergy — in either a positive, or a negative sense. Of course, for large, diverse or complex solution systems, a particular environment in which they will eventually exist and operate need not be uniform, or even consistent. This may impose requirements on the solution system, i.e., that it be able to operate in a variety of local environments and remain viable (S-MESH applies: synergy, maintainability, evolution, survivability, homeostasis).

For instance, a manned trip to Mars will see the various space vehicles comprising the mission package traversing between the planets, passing through radiation belts, perhaps experiencing the outflow from solar flares, entering the atmosphere of Mars at high speed, and finally settling on the surface to experience high winds and dust storms. The astronauts will, hopefully, exist and operate within a relatively controlled environment inside their vehicles and inside their space suits. But, all environments must be accounted for, and all may impact various features of the conceptual, remedial solution system as it moves from pure concept towards practical realization.

Environments can also be cultural, and even legal, as for example where solution system will have to operate within, say, the legal framework of US, English, Swiss, or Shariah law. Were the conceptual remedial solution, for instance, a new penal institution, a new branch of an international bank, a division of an enterprise, or a factory to manufacture products under license, then the relevant national legal and cultural environment within the country may prove relevant, and may shape the development of the remedial solution system's future design.

Structure and dynamics

Next in sequence comes 'identify SoS sibling systems.' The eventual solution system will interact with other systems in its future environment(s). There will be interaction routes, media, etc., and there may be need for communications protocols, interfaces, etc. The sibling systems referred to are those other systems that will exist in the future environment such that they all, together, constitute a wider, or containing, whole. In this context, siblings may already exist, may be expected to exist, or may even be necessary to create, to realize a containing whole.

This activity is, essentially, recreating/identifying the so-called poached egg — see page 77. It is important for the eventual solution system to be set into its containing system and to interact with its siblings, else it will not be viable, will not operate correctly, and will not have the effect which its realization intended. Undertaking this activity will enable the designer of the solution system to envisage that system in operation, interacting and adapting, acquiring resources, exchanging material and information, disposing of waste, consuming and dissipating energy, etc., etc.

Identifying the containing system, of which the remedial solution system will become part, is important for another reason. The containing system will have objectives, and the value of the remedial solution system will be measured by the degree to which it contributes to those objectives, in concert with its siblings. This degree is likely to be maximized by optimizing the developing remedial solution system's design. (Hitchins, 1992)

There is yet a third reason for this activity: it provides the foundation for the eventual simulation of the solution system in its environment, adapting to those other systems with which it will interact; it is then, an essential aspect of the systems approach, without which the performance and effectiveness of the eventual solution system could not be sensibly determined.

Resource needs

An important output from these activities is an assessment of the resources that the remedial solution system will draw upon in the solution space. This becomes apparent when considering how the remedial solution could be viable in its future environment, and is most easily envisaged when considering a brand new, or 'green-field' system.

For instance, suppose the conceptual remedial solution system were a new sensor array to be located on the far side of the Moon, away from man-made radio interference. Once constructed and set to work, such a sensor array would need to remain viable, perhaps over extended periods. Invoking the S-MESH acronym again reminds us that there are many factors to consider, each with resource implications.

- Synergy between the array elements and the sensors will have been built into the design and construction, but must be maintained in a hostile environment of wide and sudden temperature shifts, cosmic ray impacts, etc.
- Maintenance will require the provisioning of spares, and perhaps automatic repairs, or self-healing — which raises the issue of maintaining the self-healing systems. . . .
- In the light of operational experience, the array and sensors may prove to be capable of improvement or expansion, so that modifications and adaptations can be foreseen.
- Then again, the whole array must be able to survive damage from its harsh environment, perhaps through damage tolerance, or perhaps through some self-defense mechanism, which may itself be subject to maintenance.

Evidently, without knowing much about the remedial solution at this early stage, prior to design, it is still possible, and important, to consider what influences will affect the future system, and what resources will be needed both to operate the future system, and to maintain its ongoing viability.

Perhaps the most significant of the components within the S-MESH acronym — homeostasis — is worthy of special attention. Evidently, a solution system will remain viable only so long as it can maintain homeostasis; which can imply many different factors all maintaining balance at the same time. Consider, for instance, a remedial solution system as a new manufacturing plant. Once set up, it will be vital to maintain not only staff numbers, but also the necessary skills for staff; that, in turn, may necessitate either continual recruitment of people with the requisite skills, or a training system, or both. Homeostasis is required also in financial dealings for the new plant. It requires payment for its output such that it can require, and pay for, materials and parts from suppliers that can be manufactured and assembled to form new output for sale. Revenue from sales must also pay for employees, recruiting, redundancies, training etc., and also for maintenance of continual upgrade of plant and machinery: there is a need for homeostasis in manufacturing capability, too, which implies that there should exist machine vendors which can support continual upgrade.

Homeostasis is important for technological systems, too. As a simple example, consider the case where the remedial solution system concept involves a more powerful computer within the confined space of some vehicle equipment bay or hold. Homeostasis might be concerned, *inter alia*, with maintaining the temperature within the bay, such that the environment is kept within sensible limits for all the equipments in the bay. If the new computer is going to dissipate more heat than its predecessor, then there may be a need to improve the heat extraction facilities, which may in turn affect the thermal signature of the whole vehicle: in the wrong circumstances, this might prove problematic. Such considerations could materially affect the remedial solution system concept, to the point of rendering it unacceptable.

Pursuing the future need for viability in general, and homeostasis in particular, identifies not only future resource needs, *per se*, but also future 'complementary systems:' these are systems, other than the conceptual remedial solution system, which will either already exist, but may need modification, or that do not yet exist, but will be required to maintain solution system operations and viability.

The need to maintain internal balance, or homeostasis, pervades most aspects of any system. In an enterprise-as-a-system, homeostasis affects materiel, personnel, security, finance, training, production, administration, buildings maintenance, facilities maintenance, communications, information services, business intelligence, etc., etc. External resources may be subject to competition. Maintaining the steady state in the system of interest may require the cooperation of other systems, complementary systems for repairing shortage or for shedding excess. In some instances, complementary systems may be new; on the other hand, it may be that the appropriate systems exist already, but may need to change to accommodate a modified remedial solution system.

Summary

The solution space provides opportunities and imposes potential constraints on the remedial solution system, even in its conceptual state. It is important to explore the solution space early on in the systems methodology, so that the credibility of competing remedial solution systems can be assessed. It may be the case that some solution concepts would be seen as impractical, while others would invoke the need for new, or adapted complementary systems, significantly expanding the sphere of influence, complexity and potential cost of some conceptual solutions. On the other hand, it might also be the case that the remedial solution may be able to draw upon, and make good use of, resources that would be available in the solution space, so simplifying the solution system design and creation task.

In any event, the solution system will have to be 'tailored' into its future environment and will interact with other systems in that environment. Exploring the solution space enables the identification of the solution system's siblings, and their mutual containing system. This will provide the basis for assessing the absolute and relative values of competing remedial solution system concepts.

In the process, both a static ('poached egg') model, and a dynamic functional model, of the solution system in context are necessary to understand the constraints (interactions, interfaces, structures, boundaries, environments, etc.) that the eventual solution system will operate and be viable within. Understanding these at the conceptual stage allows successive stages in the systems methodology to mold the developing concept and design so that the eventual solution will operate in harmony with other within its environment.

Assignment

In addressing a complex issue, a conceptual remedial solution system has been identified as including a long-term, manned installation on the far side of the Moon. The role and purpose of this facility will be twofold: a) to act as an outbound staging post for manned missions to Mars; b) to act as an inbound staging post from deep space, zero gravity missions, where astronauts may acclimatize themselves over a period of time before returning to the full gravitational impact of Earth.

Using Figure 8.1 as a guide, explore the solution space within which this facility will exist and operate, remembering that, although it will be on the far side of the Moon for technical reasons, full communication and coordination will still be necessary, both with mission crews and with Earth Mission Control. You should include in your response, those items and influences that you consider will impose constraints or, afford opportunities, or both, for the conceptual remedial solution system.