13

The Systems Methodology — Elaborated

Géronte: It seems to me you are locating them wrongly: the heart is on the left and the liver is on the right.
Sganarelle: Yes, in the old days that was so, but we have changed all that, and now we practice medicine by a completely new method.

Molière (J.-B. Poquelin) 1622–1673)

Ideal World vs Real World

The elaborated systems methodology concerns itself, in the first instance, with establishing an ideal world solution to the problem: in the event, it could be decided that the ideal world solution, the optimum, or 'best in the circumstances' solution, might not be appropriate — see Systems Methodology: conceptual model on page 172. Instead, it may be more appropriate to move the goal posts, i.e., dissolve the problem by changing the situation which generated it. Alternatively, having discovered what the full SoS might look like and cost, and considering the degree of turbulence that would be involved in introducing it, it may be more appropriate to:

- do nothing, and live with the problem — sometimes the cure can be worse than the condition;
- use the difference between the ideal world solution system, as presented by the systems methodology, and the real world to act as an agenda for change.

This second option may be pursued by examining what would have to be done to the present system to make it more effective, i.e., more like the ideal world system. A program of change may then be introduced effectively to modify or upgrade a current system, or systems, rather than replace it lock, stock and barrel. The ideal world system would, then, serve as a marker, target, or template; i.e., something to be aimed for and hopefully achieved over time. In management speak; the two different approaches may be characterized as revolution vs evolution, where revolution makes major change in a short time, while evolution makes more gradual change over a longer period.

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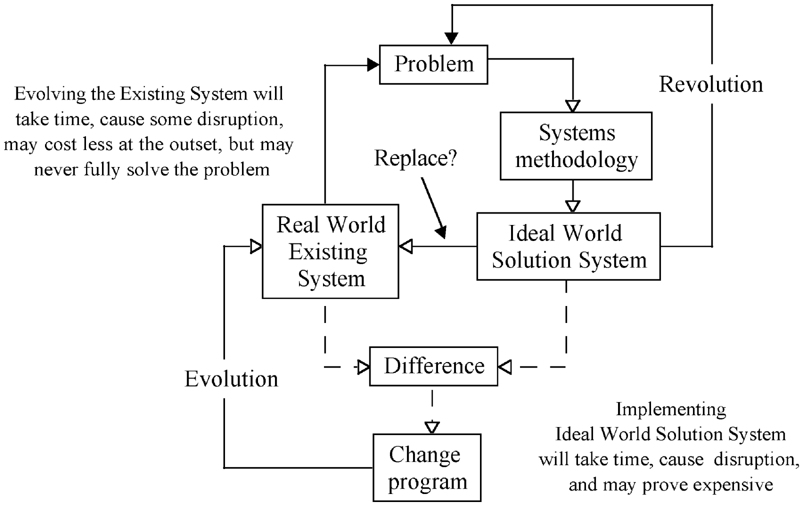

Figure 13.1 Evolution vs revolution. In the first instance, the systems methodology aims towards designing an Ideal World Solution System (SoS), which may either replace the existing system — revolution — or act as a goal design, towards which the existing system may be progressively adopted, upgraded, etc. — evolution.

The comparison is exemplified at Figure 13.1. As the figure shows, the arguments for and against evolution vs revolution can be finely balanced in terms of likely timescales, degree of turbulence, interim loss of capability while systems are either upgraded or replaced, and so on. In the final analysis, the decision is likely to be swayed as much by the willingness of decision-makers to allocate resources as by the urgency and severity of the problem. In any event, the overall systems methodology encompasses any and all of the approaches above: dissolution, resolution, or solution: and, even rationally choosing to do nothing . . . .

The Systems Methodology — as Products

The systems methodology produces a complete set of products for the SoS. These may be seen in the behavior diagrams from Chapters 7–12, and are implicit in Figure 13.2.

The Systems Methodology as a Whole

Chapters 7–12 have introduced the systems methodology as a succession of parts, with each part represented as a so-called behavior diagram:

- SM1: addressing complex issues and problems
- SM2: exploring the problem space
- SM3: exploring solution system purpose
- SM4: developing a concept of operations (CONOPS)

- SM5: design the solution system
- SM6: optimize the solution system design
- SM7: create and prove the solution system

The Systems Methodology — as Process?

Further elaboration in the form of behavior diagrams cannot be conducted here because the resulting diagrams would be too large and unwieldy. For a different perspective of the systems methodology as a whole, consider Figure 13.2. The figure shows the principal activities/processes as they might occur in going from problem space to operational Solution System (SoS). Examining the tree of processes, it is suggestive of a strategy for solving problems and creating viable, effective solutions.

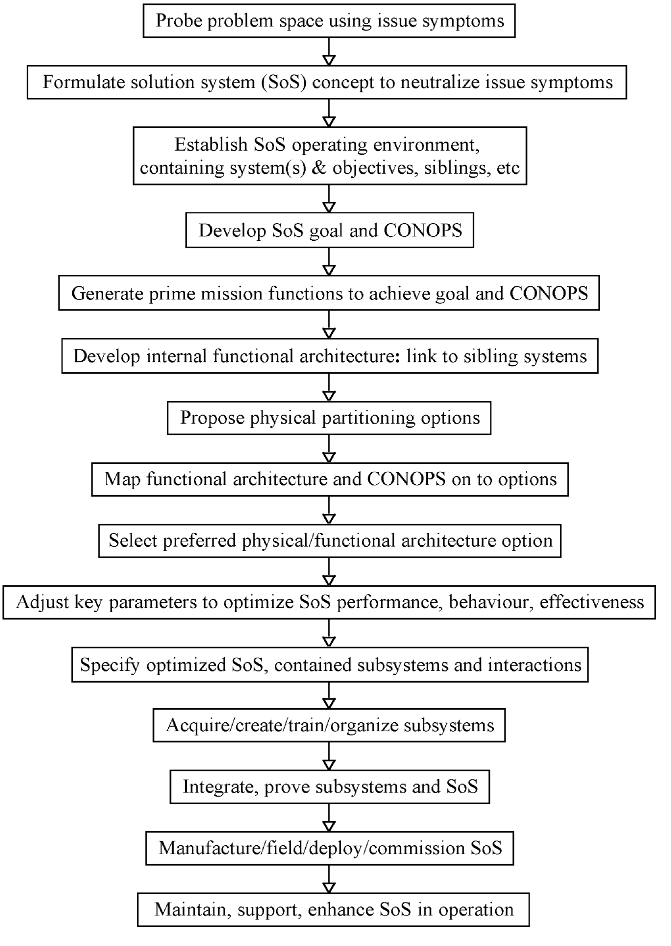

Figure 13.2 Systems methodology process / activity tree — simplified.

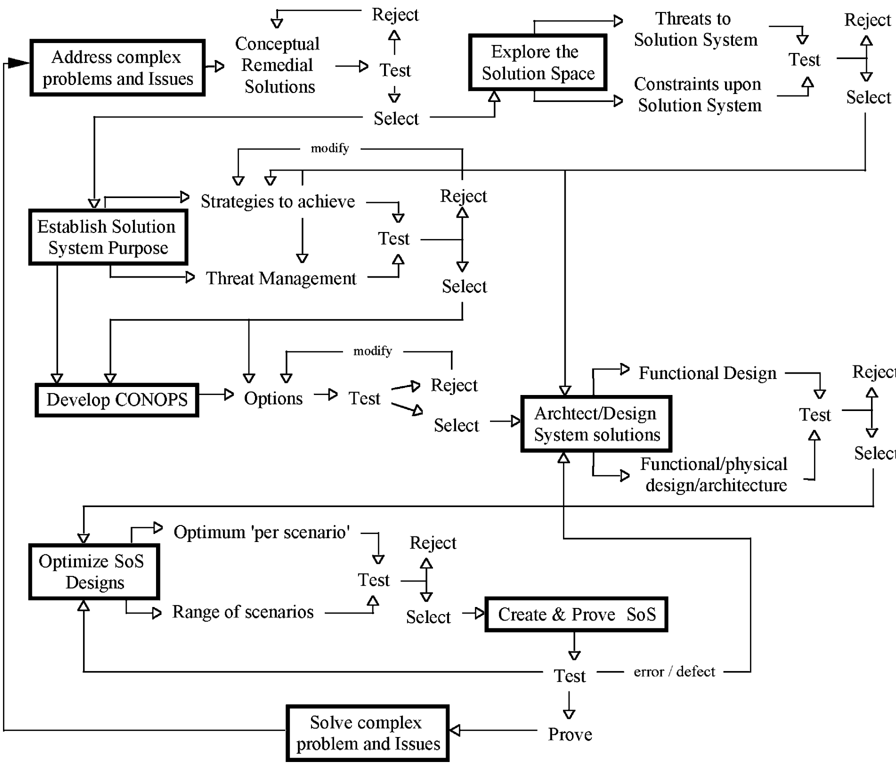

Figure 13.3 Route map, indicating the circuitous route that following the systems methodology may invoke, with testing of deductions, proving of results, etc., resulting in iterations and in the discarding of nugatory interim results.

However, the tree is not a process model, *per se*; it should not be thought, for example, that the overall process is likely to be linear. Instead, there are likely to be many recursions and iterations. See Figure 13.3, which gives some small indication of the reasons. Many of the activities and processes will produce results that have to be tested for validity, credibility, cultural acceptability, legality, regulatory conformance, etc., not forgetting their direct relevance to solving the original problem. Some tests may fail, suggesting a 'return to the drawing board,' a revision, or discarding of some potential solution or characteristic.

As Figure 13.3 suggests, for example, it would be quite possible to go around the 'conceptual remedy' loop, top left in the diagram, many times: indeed, it is by no means certain in every case that a conceptual remedial solution will be found that will stand up to scrutiny. The various iterative loops may be different in nature, too. In the case of threats, it is incumbent upon practitioners to identify threats — which may require considerable experience of the solution space, plus no small measure of insight — but at the same time not to 'over-egg' the situation by including low probability/low impact threats that may be difficult and/or expensive to address. There could be many CONOPS, each of which may need testing and evaluating, perhaps using dynamic simulations, perhaps using verbal 'walks-through;' Getting these early steps right is essential in setting the stage for effective design of the solution system; the figure shows that there can be many others, too.

Outer loop – inner loop design

A quite different kind of iteration is shown in Figure 13.4. In this case, the whole SoS design is completed at the top level, resulting in a number of complementary, open, adaptive, interactive subsystems that, together, constitute/synthesize the whole SoS. In many cases, this process/procedure will result in sufficient subsystem information to enable their creation. For some systems, however, and for some subsystems, it may be 'useful' to iterate once more, to conduct 'Inner Loop' design: that is, for one or more subsystems to be identified and elaborated in terms of its purpose (part of, and contributing to, the overall SoS purpose) CONOPS (similarly, part of and contributing to the overall SoS CONOPS), design/architecture (again, linked to the overall design and architecture of the SoS — of which it becomes an elaborated segment . . .). Such iteration would employ the same tools, techniques and methods as will have been already used, but would be more specific, would elaborate designs more fully, and so on.

Readers may recall an earlier statement that it is only possible to optimize at whole system level; optimizing a subsystem in isolation may subsequently de-optimize the whole. Conceptually, inner loop design might result in optimizing a sub-subsystem design, to the detriment of overall SoS optimization. This potential risk will not materialize if the inner loop design of subsystems and sub-subsystems is pursued with them connected and dynamically interactive; so, design elaboration requires that the subsystem or sub-subsystem to be elaborated is still an open interactive dynamic part of the dynamic, interactive, whole. This is best done, as before, in dynamic, open system simulation, where the design of the sub-subsystem can be 'adjusted' (i.e., parameters varied and selected) to sustain optimum performance of the whole.

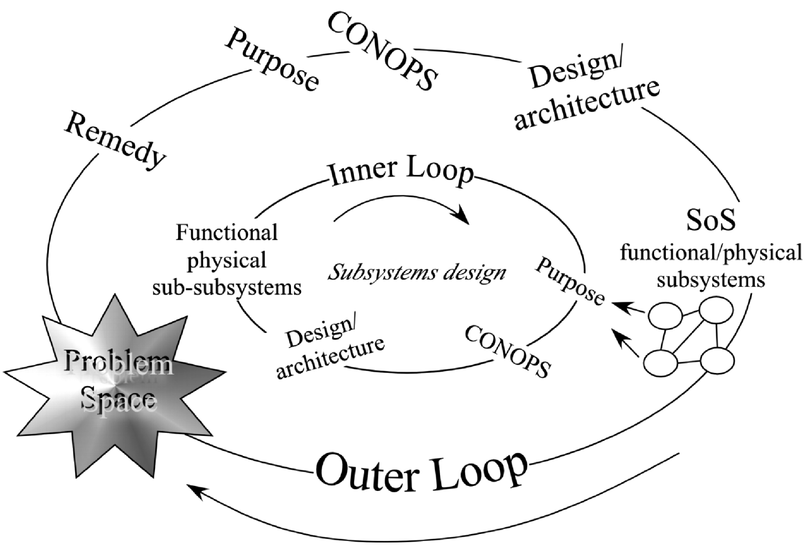

Figure 13.4 Outer and inner design loops — conceptual diagram. The outer design loop addresses the problem space and produces a solution system design of open, adaptive, interactive functional/physical subsystems. Any or all of these subsystems may then go through the same methodological process — the inner design loop. Exceptionally, it may be useful to incorporate yet another loop inside the inner design loop . . . .

Outer loop, inner loop and systems engineering

Outer loop and inner loop system design, Figure 13.4, goes some way to explain the apparent divergence of opinion about systems engineering as seen by systems thinkers and operational customers on one hand, and procurement agents and engineers on the other. It is not unusual for major customers, particularly in defense and aerospace, either to undertake the outer loop of the overall design process themselves, or to employ systems companies to do it for them. These major customers (or their system company 'customer's friend,' as they are sometimes called) may then issue specifications of requirement for some of the subsystems, and call for engineering organizations to respond, that is in effect to undertake the activities of the inner loop.

Where inner loop activities are conducted in line with the systems methodology, i.e., with each subsystem being considered as an open, interactive adaptive whole within the environment set by the other sibling subsystems and the operational environment/context, then systems engineering is clearly in operation, and the systems approach is being followed.

Where a subsystem is considered in isolation from all other subsystems, with the analysts, architects and designers unaware of, or taking no account of, the overall system, the other, interactive subsystems and their mutual operational environment, CONOPS, etc., then it would seem unreasonable to describe the activities as systems engineering; the systems approach is not being followed.

At some stage, there may arise the need to design and fabricate an artifact, with its associated interfaces, interactions, properties, capabilities and behaviors, etc. That stage may sensibly be called engineering, for that is what it is, but it may also be considered as an essential part of the overall systems engineering process — for that is what it also is. It is also practicable to adopt the systems approach when conceiving and designing artifacts, which encourages the soubriquet of systems engineering.

Discussions about perceptions of engineering vs systems engineering may also obfuscate the situation — many of the subsystems will be social and/or sociotechnical, where standard engineering practices will be inappropriate, but where the systems methodology, in the hands of good systems practitioners, will comfortably fit the bill.

The Systems Methodology — in Parts and Phases

A degree of elaboration of the systems methodology may be presented using a different form of illustration. See Figures 13.5–13.8: the figures form a contiguous set:

- Figure 13.5 illustrates SM Step 1 Explore Problem Space, and Step 2 Explore Solution Space.
- Figure 13.6 illustrates SM Step 3 Focus SoS Purpose, Step 4 Develop SoS High Level CONOPS, and part of Step 5 Design SoS.
- Figure 13.7 illustrates the second part of SM Step 5 Design SoS, and Step 6 Optimize SoS Design.
- Figure 13.8 illustrates SM Step 7 Create and Prove SoS.
- Together, the four figures present one view of the elaborated systems methodology.

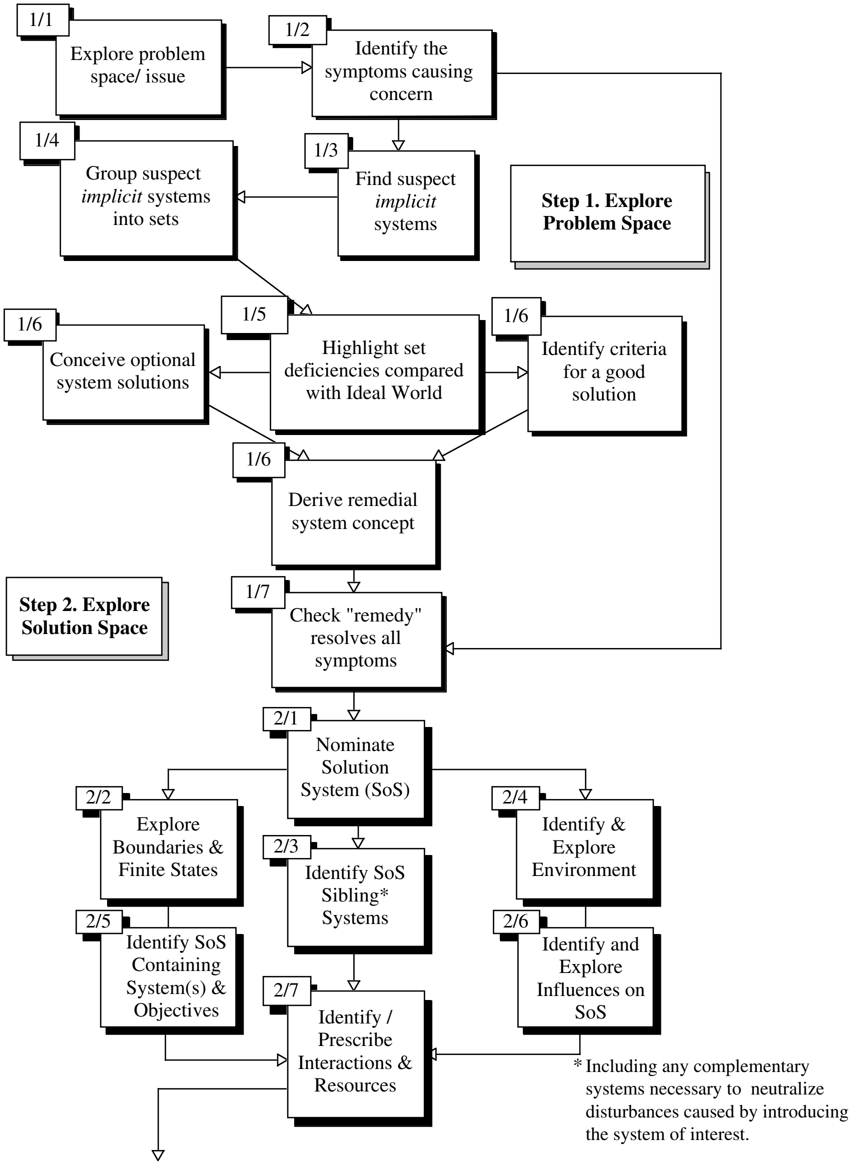

Figure 13.5 Systems methodology high-level process view, Steps 1 and 2.

Note that Figure 13.8, Activities 7.2 and 7.3, incorporates some possibly unexpected inputs, concerned not so much with the nature of the SoS, but more with the nature of the environment in which the systems methodology manifests itself. The systems methodology is a complex system in its own right; it is open, adaptive, interactive, and may even be vulnerable to threat and attack.

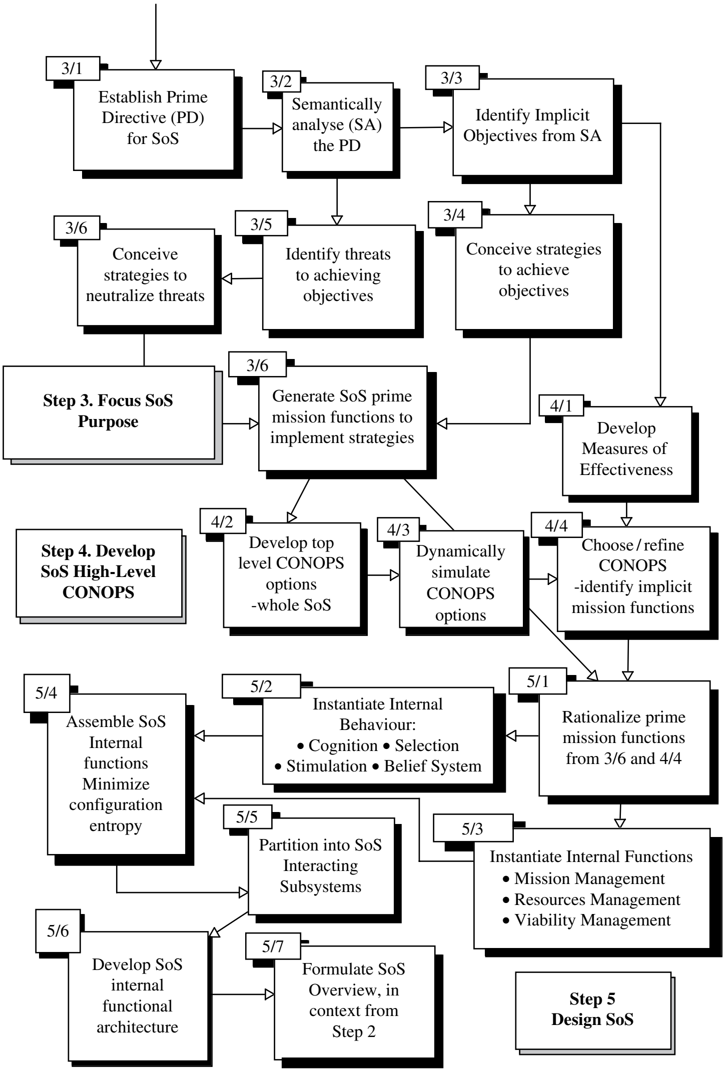

Figure 13.6 Systems methodology high-level process view, Steps 3, 4 and (part of) 5.

This becomes particularly relevant to achieving the intended outcome — a viable, enduring solution to the original problem — during the creation phase, where the SM, the team conducting the process, and the resources they require to drive the process forward may be threatened by competing projects, may be denigrated by competing reductionist processes as time consuming, expensive, etc., all of which will divert effort away from prosecuting the systems methodological process, and may prejudice a satisfactory outcome.

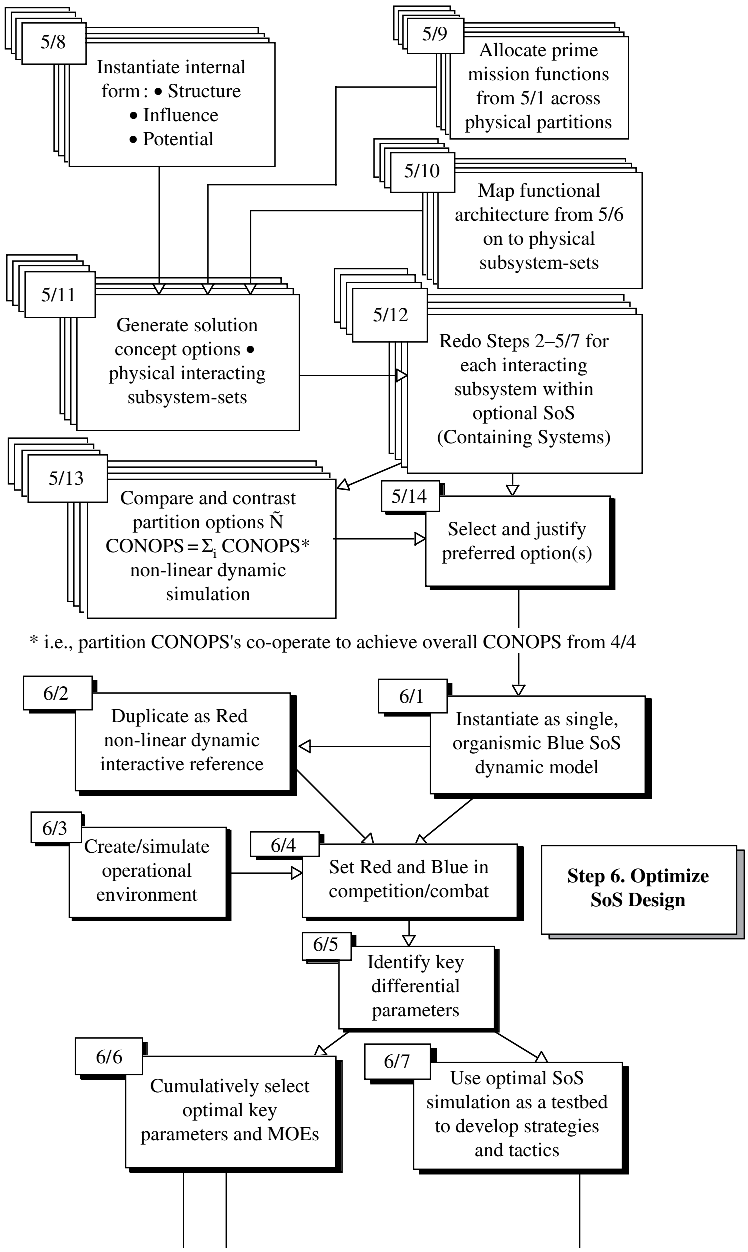

Figure 13.7 Systems methodology high-level process view, Steps 5 and 6.

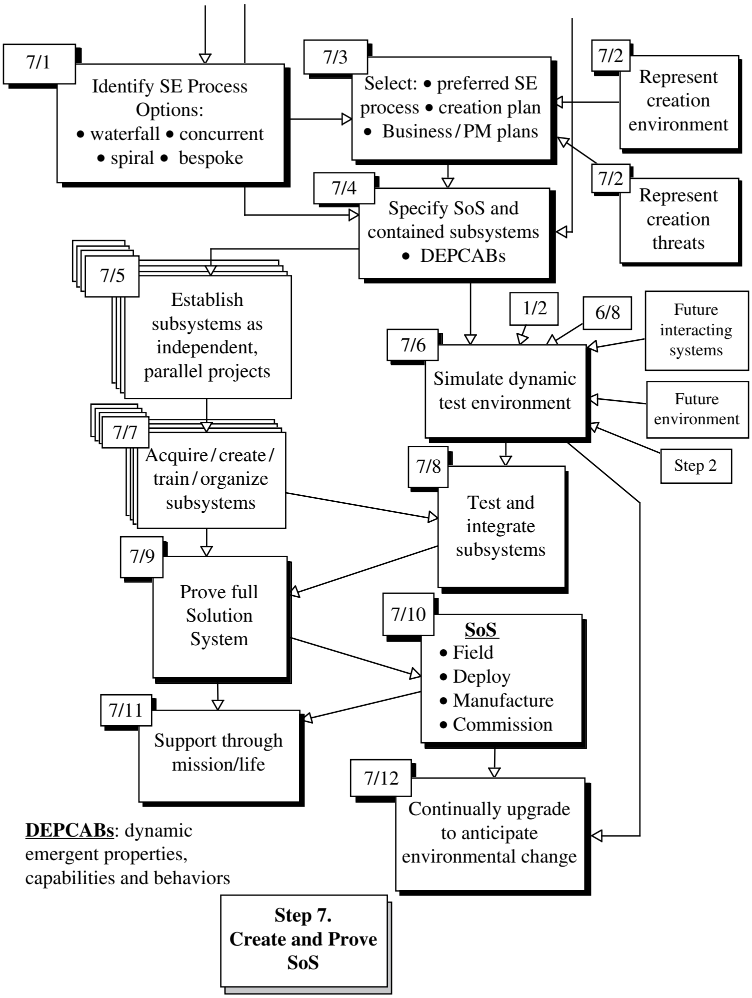

Figure 13.8 Systems methodology high-level process view, Step 7.

Summary

The elaborated systems methodological process is, in the first instance, targeted at creating an ideal world, or optimum solution system (SoS). However, in the overall systems methodological approach to problem solving, this may be only a preliminary stage: see Figure 6.4 on page 175, where the three of the four possible outcomes are shown: dissolving, resolving and solving the problem. The fourth possible outcome, having reviewed the first three, would be to choose to do nothing; that is, to 'live with the problem.'

The full systems methodology, then, encompasses all of these optional outcomes. The systems methodology process/procedure (as exemplified in the behavior diagrams of Chapter 12, and the process or activity models of this chapter), on the other hand, concentrates on designing and creating the ideal world whole SoS, or best solution in the circumstances, since that serves as a marker by which to judge the best course of action.

If the ideal world, or optimum, solution is chosen, then the process is straightforward — create, prove, introduce, work-up, and continually evolve the whole. If a less than ideal solution is chosen, one that still solves the original problem but which perhaps has less than ideal properties, capabilities and behaviors, then the process is equally straightforward. A less-than-ideal solution may be quicker or cheaper, or both, in the short term, for instance, and may even be a wiser choice in a particularly turbulent or uncertain environment, where a SoS's useful life may be relatively short.

The systems methodology may be viewed in part as a process, or series of activities — of course, that is only a small part of the story, since addressing the processes and activities requires experience, expertise, tools, techniques and methods. However, the process/activity charts tell a story, indicating the broad strategy and sequence of activities, with the generic reference model providing a series of waypoints or markers, navigating forwards from the problem space, and backwards from the solution space to provide a design that is intended to satisfy both problem and solution.

It should not be thought, however, that the path through these activities is linear, from start to finish. Instead, the route finds its way through a landscape of infinite possibilities and probabilities, with tests, rework and iterations along the way. At a number of points, options are generated and pursued before some of them will be dropped. A wide spectrum of threats may be generated and examined, but not all of them addressed, perhaps because of low probability, low impact, or high cost. And so on. Barely concealed then within the elaborated systems methodological charts of this chapter are blind alleys, elaborate iterations, etc., many of which should be explored to maintain rigor in the method — sometimes a seemingly blind alley turns out to be an innovative, even radical, new idea.

The outcome of the 'top level' design activity is a set of complementary, open, interacting and adaptive subsystems. Some of these may be social systems, or human activity systems, as in an enterprise, a military formation, a disaster relief organization, or a team. Others may be sociotechnical, as in a command and control system, an assembly plant, a passenger transport aircraft, a lean volume supply system, an F1 (Formula One) racing car team, etc. There may be need/advantage in iterating the systems methodology for these subsystems, particularly the sociotechnical ones, with each subsystem being considered as the whole, with its own requisite dynamic emergent properties, capabilities and behaviors (DEPCABs). Each subsystem would be addressed in the same way as the whole, i.e., as an open, adaptive system, interacting with its siblings and with other systems in the solution space: so, still fully connected and interacting, using the same dynamic simulation approach.

In this context, it is reasonable to view the top level of design as the outer loop, and this second 'go around the system' as the inner loop. Inner loop activities will elaborate subsystems into open, interactive sub-subsystems, some of which may turn out to be specified as exclusively technological.

Assignment

You apply for a position as a Systems Design Manager, to be responsible, with a team of specialist systems engineers and designers, for establishing the avionics design of a new air defense fighter aircraft. You are surprised to be given the job. On arrival in your new position, you set to work, trying to find out all you can about this new fighter and its avionics system, which you know comprises navigation, communications, flight management, primary and secondary radars, weapons and weapons management, processors, data highways, etc., etc. You are able to find plenty of technical data about the various technological subsystems that are to form the avionics system, but you can find no trace of any concept of operations (CONOPS) for the fighter in its air defense role.

Do you:

1. Press on regardless, without a CONOPS, and proceed with the processes of integrating the various subsystems, reasoning that the CONOPS is for operators anyway, not for systems engineers
2. Concoct a typical CONOPS by talking with air defenders, particularly those who have operated previous fighters in the air defense system, and who know how it worked with earlier types of fighter aircraft
3. Ask the customer, a government procurement department, for the approved CONOPS — knowing that there is none
4. Set up an expensive and time-consuming operational analysis, using one-on-one and many-on-many combat simulations, in an effort to find out what the CONOPS should be?
5. Something else. . . ?

Consider the above (real world) dilemma, discuss the options, choose and justify your course of action. N.B. You do not need to know anything about fighters, air defense or avionics to undertake this assignment.