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SM3 and 4: Focusing Solution System Purpose

The Englishman never enjoys himself except for a noble purpose

A.P. Herbert 1890–1971

SM3: Solution System Purpose

The previous chapter explored the solution space, seeking constraints and opportunities that might influence the concept, design and, indeed, the validity of a conceptual remedial solution system. Using that knowledge, it is feasible to explore the nature of the conceptual solution system. Since, in general, we will be addressing man-made systems (in the broadest sense), then it is appropriate to focus attention on the purpose of the conceptual solution system: exploring and expanding on a system's purpose will enable that system's effect and effectiveness to be envisaged, and will also concentrate design effort towards a specific end.

A useful approach to the consideration of a system's purpose is to appreciate its prime directive — a term incorporated from the life sciences. The prime directive of a system is a statement of its ultimate purpose. Such a statement gives no indication of how that ultimate purpose is to be achieved. For Man, it may be described as propagation of the species, where propagation requires not only procreation, but also nurturing and protection of offspring until they, too, are of sufficient maturity to sustain the propagation process. That example shows the value of the prime directive: it rises above the details and gets to the nub of purpose.

However, that example is less than ideal in another respect: all animals on the planet have the same prime directive; they all seek to propagate their species, making that particular prime directive rather poor as a differentiator. We must be more specific to identify the purpose of a particular system solution.

For instance, the prime directive (PD) of a government might be: 'to provide a secure, prosperous environment within which the population may develop and flourish.' The PD is deliberately bare, and contains only one verb, to ensure only a singular purpose. Similarly, the PD of a marketing department might be: 'to position the company so as to flourish in a competitive market;' indicating that the role of the marketing department is one of positioning, not one of selling.

Systems Engineering: A 21st Century Systems Methodology Derek K. Hitchins

Developing a PD for a new system is a significant aid to objectivity, but by itself, it is not enough. To be useful, it has to be associated with a strategy, identifying how the ultimate purpose expressed in the PD is to be achieved. There may be alternative strategies, or ways to achieve the prime directive. Moreover, each of the strategies might incur different risks, might experience threats. So, there are three parts to a 'useful' PD: the statement of ultimate purpose; the statement of strategy for achieving that purpose; and, the threats envisaged that prejudice the strategy.

Looking back at the PD for Man, we can see that the strategy adopted by early man was to develop family units, and for groups of families to form communities for their mutual protection and for cooperative hunting, gathering, etc. Threats included natural disasters, predation by wild animals, shortage of food, and possible raids by other social groups, so that early man chose to operate by day, and shelter by night. Evidently, the strategy generally overcame the threats, so that the PD was observed — else we would not be here.

Threats and strategies

There may be one PD, but many threats and many strategies. It can be seen that strategies come in two 'types:' those to achieve the PD 'unopposed;' and those to overcome the threats to achieving the PD.

It is often useful in practice to analyze the PD, using a technique called semantic analysis: this enables the PD to be envisaged as a sequence of objectives. Take, for instance, the PD for a national air defense system, which might be: 'to neutralize enemy air incursions into national air space.' This might be semantically analyzed as follows:

To neutralize. . .	To eliminate the threat from. . .
. . . enemy. . .	. . . those declared by government to be hostile who. . .
. . . air incursions. . .	. . . enter by air without permission. . .
. . . into national airspace	. . . into the airspace legally defined and internationally promulgated as sovereign, national airspace

Implied means: national air defense assets — surface-to-air missiles, airborne interceptor aircraft, beamed energy weapons. . .

Semantic analysis expands the PD, term by term, into an almost legalistic expression. Using the semantic analysis allows a sequence of objectives to be identified: delineate airspace boundaries; detect air incursion across boundaries; identify intruder; classify intruder as friendly, neutral or hostile; neutralize hostile intruder. Neutralize is a military euphemism, which could mean any of an escalating range of actions, according to the 'temperature' of the situation and the nervousness of the defenders: warn off, escort out of airspace, force to land; render intruder's weapons ineffective, shoot down. . . .

Figure 9.1 illustrates the developing process in the form of a behavior diagram. The diagram center panel starts with developing a prime directive for the conceptual solution system. This PD is then semantically analyzed and a sequence of objectives is derived, the final one of the sequence being the 'mission' objective. Threats to achieving each objective are considered.

Strategies are then conceived for achieving each objective. (The conception of effective strategies requires an understanding of the solution space/the operational environment in which the solution system will seek to achieve its purpose.) There are two kinds of strategy: those for achieving the

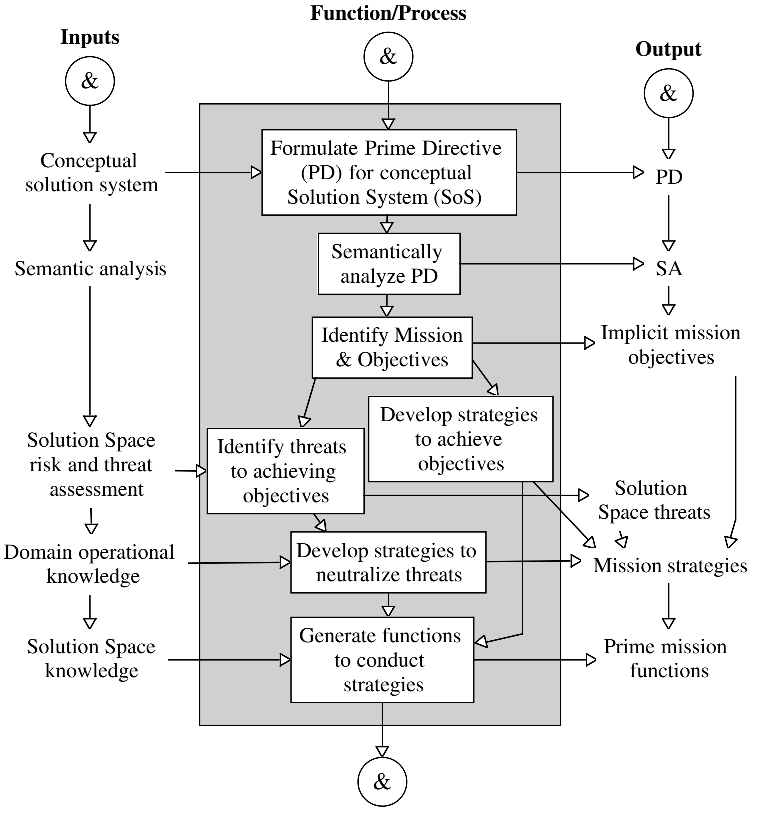

Figure 9.1 The TRIAD building system: purpose and threat management.

objective unopposed; and, those for overcoming threats to achieving the objective. All of these strategies become the mission strategies because they all have to be effective in order for the mission to be accomplished.

Finally, the various strategies are addressed as prime mission functions that the solution system has to be able to perform to achieve its mission in the threat operational environment. The overall process is referred to as the TRIAD building system (Hitchins 1992, 2003) because of the repeated occurrence of the three elements: objective; strategy to achieve objective; and, strategy to overcome threat to achieving objective. The technique is powerful, creative and insightful; moreover, it generates a considerable amount of information pertinent to the design of the overall solution system.

(The TRIAD Building System can be used as a method or technique for addressing, not only the developing system solution, but also for addressing the systems methodology itself. If the application of the systems methodology is considered as a system project, then that project may be envisaged as existing/surviving in an environment — often that of the organization or company that is ‘hosting’ the project. It is feasible, then, to identify threats to the continuation of the project, strategies to achieve the projects objectives, and strategies to neutralize the threats at the same time.)

The range of threats that is identified and neutralized will vary for any given solution system concept according to the capability, experience and insight of the team members concerned in applying the systems methodology. In practice, there may be a delicate balancing act to perform. On the one hand, the experienced team may perceive many more threats and generate prime mission functions to address them, resulting in a more complex and potentially more costly solution. On the other hand, the inexperienced team may perceive fewer threats, may generate less credible strategies to address those threats, and may consequently generate a simpler, and potentially cheaper solution.

Which is better? All things being equal, the more capable solution might be preferred, but may be less affordable. However, it is not necessary to judge at this early stage. Later in the systems methodology opportunities will arise to 'try out' the solution system design, operating in a typical environment containing a range of threats, and it will then be possible to assess the value of features of the design that have been incorporated specifically to address particular threats. Moreover, the cost of the end solution system is less related to the complexity of the design, more related to the manner of its creation. For technological elements, in particular, the same prime mission functions may be performed by different technologies of widely different costs: it is too soon in the systems methodology process to be unduly concerned with cost, and besides, integrity requires that, initially at least, we conceive the best solution.

SM4: Developing a Concept of Operations (CONOPS)

Focusing on Purpose would be incomplete without identifying how Purpose was to be achieved: the way a solution system is expected to work, operate, create the desired effect, etc., may be referred to as its concept of operations, or CONOPS. It is quite possible, even usual, for a remedial solution system to be associated with more than one CONOPS. Competing CONOPS then vie to be the best, or preferred CONOPS, where best is judged according to derived measure of effectiveness — value judgments.

As a concrete example of CONOPS, see NASA's Apollo on page 84: there were many competing CONOPS, each being tested step-by-step throughout a simulated or imagined mission, until the best, most likely to succeed, emerged as the preferred CONOPS.

At a more prosaic level, consider a remedial solution to a particular national energy problem, where the solution system has been conceived as an extensive wind turbine system. Simply stating 'wind turbine system' is clearly insufficient. How it is it expected to work, as a generator of electrical power in the context of national power generation, with other sources of power also available? Where is it to be sited? ? Wind power, of course, works best when there is a wind, and wind, as we are all aware, is a highly variable commodity. What happens when there is no wind: is the locale deprived of power? What happens when there are gales and hurricanes? Must the wind vanes be feathered, to avoid damage from over-rotation in strong winds? Would feathering result in no power generation, normal power levels, or what? What if peaks in power generation coincide with troughs in demand? Can excess generated power be stored? How?

By stepping through processes of generating wind power under a range of environmental conditions, possibly storing excess power, coupling to the national grid, and drawing upon previously stored energy reserves, it becomes clear that there are many options along the pathway, and that some are preferable to others in terms of risk, response times, expense, performance, effectiveness, efficiency, etc. For example, excess energy might be temporarily stored in batteries, by raising water into a reservoir, in large flywheels, etc., etc. It also becomes clear that, in many cases, generating wind power may turn out to be much more about regulation, control, switching and storage, than about windmills — they are the relatively simple, if highly visible, part.

So, the development of a CONOPS may be seen as creative, with competing CONOPS being compared using value judgments to select that which is best of those on offer. Both aspects, the selection of CONOPS and the process for judging between competing options, require that the analysts/architects have an intimate knowledge and understanding of the solution space, the operational environment and the constraints, opportunities and likely threats within it.

Figure 9.2 shows the process for developing a high-level CONOPS, in the form of a behavior diagram; this diagram follows from that of Figure 9.1, above: note, in particular, that the input, top left to the first activity, top center, includes solution domain knowledge, mission objectives and prime mission functions. With these inputs, indicating what the purposeful solution system is expected to achieve, it is possible to generate one or more concepts of operations, initially perhaps in the form of a storyboard: sketches, rich pictures, sequence diagrams, even cartoon-like strips, etc., as needed to illustrate 'how things are meant/expected to work.'

With any complex solution system, containing system and environment, it is likely that there will be several CONOPS, competing for the top spot. Choosing between them requires, next, the development of a robust set of so-called measures of effectiveness (MOEs). These are values for the solution system, and particularly for its performance, that will be prized by the owner/user of

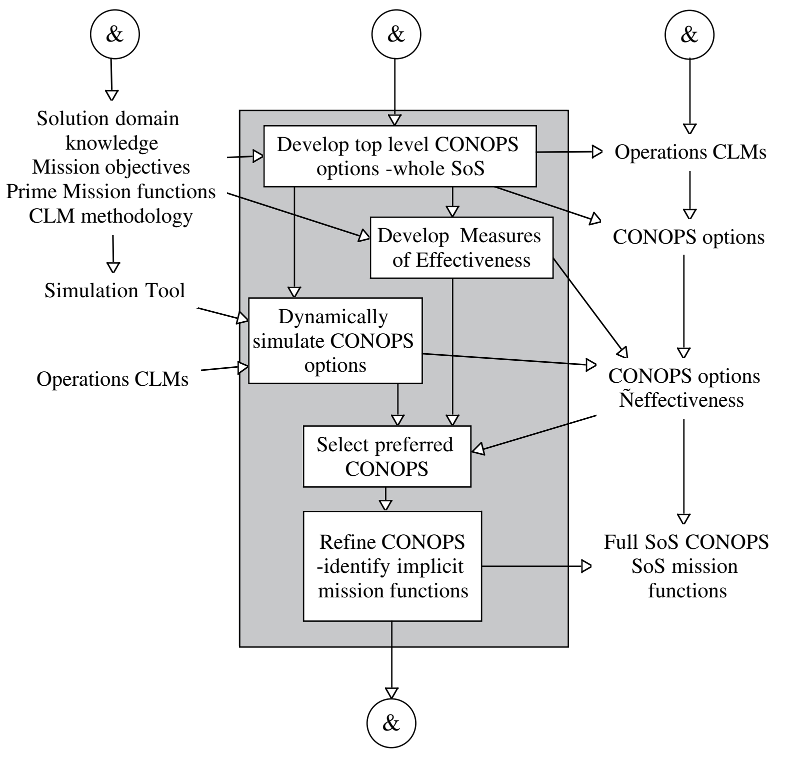

Figure 9.2 Developing a sound concept of operations (CONOPS).

the solution system. According to the mission, they may include probability of mission success, timeliness, viability, degree of effect, reliability, survivability in the face of threat, affordability, integrity, security, resources and logistics, etc.

The high-level CONOPS options may next be simulated dynamically, to assess the impact of interactions within and between systems, timeliness, resource implications, etc: this is an important aspect, since it allows the various system parts to interact and to adapt, to draw upon resources, to demonstrate potential performance and effectiveness. Simulations of competing CONOPS provide a cogent basis for choosing between them, setting simulated performance against the MOEs as basis for rational choice. Not only does the simulation process provide the basis for comparative judgment, it should also provide an absolute measure, since some (or all) options may be seen not to achieve the mission satisfactorily. If none is satisfactory, then either a refinement process is needed to improve the preferred option(s), or new and different CONOPS may be generated and simulated.

It is by no means certain that an acceptable CONOPS can be found. Where that is the case, then it may prove necessary to revisit the process of identifying the solution system: in such cases, it is possible that the answer is neither so solve the problem, nor to resolve it, but rather to dissolve it, i.e., to move the goal posts.

Behavior diagrams, such as Figures 9.1 and 9.2, may give the impression that the systems methodology is linear, but the reality is that the processes tend to be repeated as their outputs are seen to be incomplete, inadequate or even incorrect. Happily, the facility for seeing that the outputs are incorrect is built in to the processes, in this case into the dynamic simulation of the competing CONOPS, since the acid test for the simulation must always be whether it demonstrates that the original problem symptoms will be neutralized, or not.

Assignments

1. Formulate a prime directive for a university, semantically analyze the PD, identify a sequence of objectives and a mission for the university, suggest threats to the achievement of those objectives, and strategies that will both overcome the threats and achieve the objectives. How might you establish credibility for the strategies that you have proposed?
2. Formulate a prime directive for a horse-race gambling system, and repeat the activities above, in 1.
3. As part of the solution to an impending national energy shortage, a robust and extensive advertising and publicity campaign is proposed by government to persuade the people and the anti-nuclear lobby that nuclear energy will be an essential part of the future national energy strategy. Establish a concept of operations for the publicity campaign-as-a-system, presuming the campaign to extend over at least three years. Develop MOEs by which to judge the efficacy of the campaign. Consider how the campaign might sensibly be simulated dynamically, and discuss the value of such a simulation were it to be undertaken. Consider, also, whether or not your personal attitudes to nuclear power impose themselves during this exercise, and how you deal with any such imposition.