have to operate in battle management mode rather than point defense or perimeter defense mode. With this in mind, the question of whether the Soviets were deploying NMD was analytically reduced to four atomic questions, all potentially answerable from available intelligence methods.

1. Were the SA-5 and SA-10 interceptors dual purpose SAM/ABMs?
2. Were the Hen House and Pechora-class LPAR radars passing target tracking data to missile defenses?
3. Was there a central ABM command authority with a command, control, and communications (C3) system?
4. Did the SAM/ABM missiles have nuclear warheads?

All NIE participants agreed that if the answers to these questions were "yes", and they were, then the Soviets were deploying NMD (Lee, 1997).

Several things are noteworthy about these questions. The overarching feature of systems analysis in this case was that inferences of purpose (NMD) and function (ABM) were being made without any testimony of the system's designers, which would become available in the 1990s, corroborating the analysis. The inference was based only on externally discernible characteristics of the system, on capabilities that NMD systems should have that air defense systems would not, given rational and economic relationships among system elements under the constraints of prevailing Soviet technology.

All four atomic questions address issues of function or purpose though analysis of relations. For instance, the distinction between a SAM and an ABM depends on how the interceptor is integrated with its associated radars, specifically with the function that the interceptors and radars co-produce. Similarly, whether the SA-5 and SA-10 interceptor missiles had nuclear warheads depended on the proximity of nuclear storage facilities to the missile launch sites.

This case also illustrates another characteristic of systems analysis of artificial systems, that the analysis often develops functional ascriptions which contradict the claims of authorities, a characteristic documented in Ackoff's many writings on his analyses of government and UN agencies, corporations, charities, etc.

5.3 Failure of Systems Analysis

The failures of systems analysis described by Lee in the analysis of Soviet NMD are instructive. For instance, the failure to rationalize the sequence of tests at Sary Shagan and the failure to understand the relationship between the Hen House and Dog House radars (in fact there was none) were both due to the same mistake, made by analysts at the beginning of Soviet missile defense deployment in the early 1960s and corrected a few years later: what was in fact two separate systems, with distinct interceptor models, distinct radar models, and distinct areas of responsibility (Moscow on the one hand and the Soviet Union on the other) was analyzed as though it was all one system whose area of responsibility was a topic of contention.

The same kind of mistake, failure correctly to delimit the system, was a contributor to, but not the complete cause of, Galen's errors, e.g., Galen's faulty analysis of the heart, based on a cardiopulmonary rather than a cardiovascular system, concluded that the heart was a furnace receiving *pneuma* through the pulmonary veins. The problem of correct delimitation of a system in systems analysis remains difficult, and inspiration remains part of the solution (Zandi, 2000, amplifying Churchman, 1971; 1979).

It is important to note in the case of Soviet NMD that the consequence of initial failure properly to distinguish and delimit the systems was not a conclusive faulty analysis, but rather failure of the analysis to converge. This is characteristic of systems analysis, that rather than confidently reaching erroneous conclusions from false premises, it dissolves into a muddle when its underlying premises are incorrect. Had Galen insisted on necessary rather than plausible explanations, he might also have failed to converge on explanations of human physiology, instead of reaching conclusions that were detailed, consistent, plausible, and wrong.

6 Conclusion

Systems methodology has been presented as a complementary approach to systems engineering on the one hand, and systems analysis on the other. The element common to both was shown to be design. Design in systems methodology is the combination of two interactive loops, one addressing the relationship between the design object and its environment, the other addressing the relationship between the design object and its elements.

The design approach to analysis considers structure, function, and process in the context of environment to develop information, knowledge, and understanding of the system and elements being studied. In the systems approach, process and structure combine jointly to produce function in the context of environment. This method was shown to be capable of discerning functions and purposes that were not apparent from structures alone, or from analogy with structures of known function.

This chapter has presented the interactive loops of the design process in systems engineering, and the use of analogous interactive loops in systems analysis. The modern systems analysis methodology of Gharajedaghi, Ackoff, and Churchman, built on the foundation of Singer, has been generalized to correspond to Harvey's actual method, and to modern methods of military intelligence analysis of large integrated technical systems.

Systems analysis undermines the purported distinction between natural and artificial systems, separates design from designers, and presents a practically successful account of design function at odds with current philosophical accounts.