CHAPTER 1

The Architecture of the Autonomous System

A system of thoughts must always have an architectural structure.

—Arthur Schopenhauer, *Die Welt als Wille und Vorstellung*[1]

1.1 INTRODUCTION

The main objective of this chapter is to introduce the architecture of an autonomous system. This requires several clarifications, in that the architecture is not presented as an hypothesis or theoretical work, but as a design object to be built. It is therefore presented in the spirit, fashion, and format as commonly done in the preproject phase of a proposed mission or project.

1.2 THE SYSTEM CONSTELLATION

It was our original intention to provide a Level II description of the software architecture. However, it became very clear that from a computer science software architectural perspective, the mind is not a single system but a "system of systems," better described collectively as a *constellation*. Nor can such an enormously large object as the human

The Autonomous System: A Foundational Synthesis of the Sciences of the Mind, First Edition. Szabolcs Michael de Gyurky and Mark A. Tarbell.

mind be implemented as single system with a number of subsystems. Such an undertaking would be exceedingly difficult to design because the interfaces and subsystems would become too numerous, too complicated, too difficult to identify for design purposes, and overlapping/intertwined in that some are separate systems and others are functions and processes that permeate numerous systems.

During the period in which the *Critiques* et al. were written, German as a language was in a state of change, and the various authors, although thinking in terms of systems (σύστημα or *sustēma* in Greek), had no idea of the distant development of computer science and its potential as a tool for replicating human functions. The object, therefore, is not a single system with dedicated subsystems, but a constellation of nearly independent, unique entities or systems. Onward, we will call this replication of the human mind the *system constellation*. Thus, the architectural design will need to be presented at Level I. This will apply to the overview of the system constellation as a whole, as well as to each of the systems within the constellation presented in the chapters to follow. For a design team to flesh out and complete this architecture at the lower implementation levels, there must be a clear starting point for a disciplined systems approach to begin, or the goal will never be reached.

Note that even though the emphasis herein is necessarily on the software (mind) domain of the systems architecture, care must be taken not to forget about the hardware (brain and sensory) domain. Being mindful of the hardware required to support the software design helps to put the entire system constellation into proper and understandable context and perspective. This will also help to ensure a realizable system when the time comes for implementation. After all, it is the hardware and sensors that provide the processing capacity and communications connectivity of the system constellation. Nevertheless, the hardware design portion comes only after a complete software architecture has been designed, for it is the hardware design that supports the software design, not the other way around. This process is one of visualization—it was Hegel's quantum that offered the first doors of visualization into the architecture of the mind and the relationship it had to the brain. The architecture of the brain is based on the information processing requirements of the mind and—as is true in any flight project—the associated communications and sensory requirements.

1.3 SYSTEM CONSTELLATION ARCHITECTURAL OVERVIEW

There are in the human brain two separate but linked hemispheres. The two hemispheres have similar architectures or anatomies, and for the sake of this design, they are treated as equal. The conclusions of Arthur Schopenhauer reveal a very intriguing phenomenon. He states that the *Idea*[2] (i.e., pure reason, not based on empirical experience) in a thought process originates from that part of the mind dedicated to the arts, such as music, poetry, and art. The *Concept*[3] (i.e., empirically derived understanding) in a thought process, however, originates from that part of the mind dedicated to science and engineering.

Thus, at the time he was making this observation, Schopenhauer established that the right hemisphere tended to support artistic thought, and the left hemisphere tended more to scientific and engineering-oriented thought.[4] This is important in the design of an autonomous system in that such a system must be able to take a thought process from the Idea to the Concept. In human beings, where the two hemispheres are tightly coupled, this arrangement lends itself to a tremendously powerful capacity for thinking, problem-solving, contemplation, and decision. This is indeed true only of some human beings, not all. However, for the purposes of the autonomous system, we can view the left/right dichotomy of the human brain as an implementation detail, and one of biological expedience. Since in the human mind, the ideational systems (Reason, Presentation, and Understanding) generally interact among themselves more than they do with the conceptual systems across the divide (e.g., Will, Intellect, Sensory, and Decision), and vice versa, this tightly coupled arrangement would benefit their mutual interoperation. In the autonomous system, such a design may also prove to be useful should the processing requirements be so high that it becomes necessary or desirable to do so. (One must always keep in mind, however, that the elements of the design of the mind of the autonomous system such as this ultimately will be dependent on the requirements posed by the sponsor.)

There are certain ground rules for such a machine. One such rule is that it must have an image of *self*, that is, it will be conscious of *being*. Being, or being self-aware, means that it must be able to think and to contemplate. It must be able to receive instructions, learn, be receptive to instructions and orders, and carry them out. It must be able

to make rational decisions without human input, and act upon those decisions. Finally, it must be able to communicate with man, with other autonomous systems of its kind, and also among its own internal systems in the *human language* it is given by design. Thus, it is imperative to acknowledge that language is far too important in an autonomous system to be glossed over. It pays a dominant role in the way we think, read, write, and communicate, listen, and understand. So it is with the autonomous system.

The functional capability for a man-made machine to be able to think is a very serious one. As will be seen in the architectural overview, *all of thinking is a function of communication (language) among the numerous systems of the constellation*.[5]

For ease of understanding, the architecture is presented in terms of acceptable reality.[6] The eight systems that comprise the autonomous system constellation are identified and defined according to the methodology attributed to traditional systems architecture and engineering practices. This approach will first identify those systems that have been addressed in detail in the form of functional requirements or functional descriptions. The systems that are stated, having been identified, are then followed by those systems that are implied by the stated functional requirements/description, keeping in mind that very often, functional requirements and functional descriptions are interchangeable.

Because we are looking at the masterworks of the great thinkers of the eighteenth century not from the perspective of contemporary students of philosophy, but as computer scientists, we have to read these works as functional requirements and functional designs. The first thing that we are confronted with is that the terms intelligence, presentation, reflection, understanding, reason, and so on are often used in different ways, as systems in themselves, or as processes or products. For the sake of a rationally designed system, the architecture must be inferred and the design put into logical and understandable form. Exactly where a function or process takes place is not nearly as important as its product and quality.

The last step in this process—identifying those functional requirements not explicitly stated or implied—is finished by identifying the derived functional requirements and descriptions. The systems that are derived are usually those that the architect or systems engineer feel are needed to make a system work properly, without interruption, and which

are available to the user or designer on a virtual basis. In this category would fall, for example, redundant processing systems and the like.

1.4 THE CONSTELLATION ARCHITECTURE

Figure 1.1, Figure 1.2, and Figure 1.3 show three different depictions of the architecture of the system constellation. Figure 1.1 shows a simple line-art schematic of the basic entities in flat space. Figure 1.2 depicts a three-dimensional cutaway view of the constellation, showing the systems and how they embed in the Noumenon and Phenomenon regions. Figure 1.3 depicts an overhead 3D view of the constellation, showing the various systems and their arrangement.

In each of the figures, the outer sphere surrounding the systems of the constellation is the external communication network, the Phenomenon network. This network is the network of the senses, which

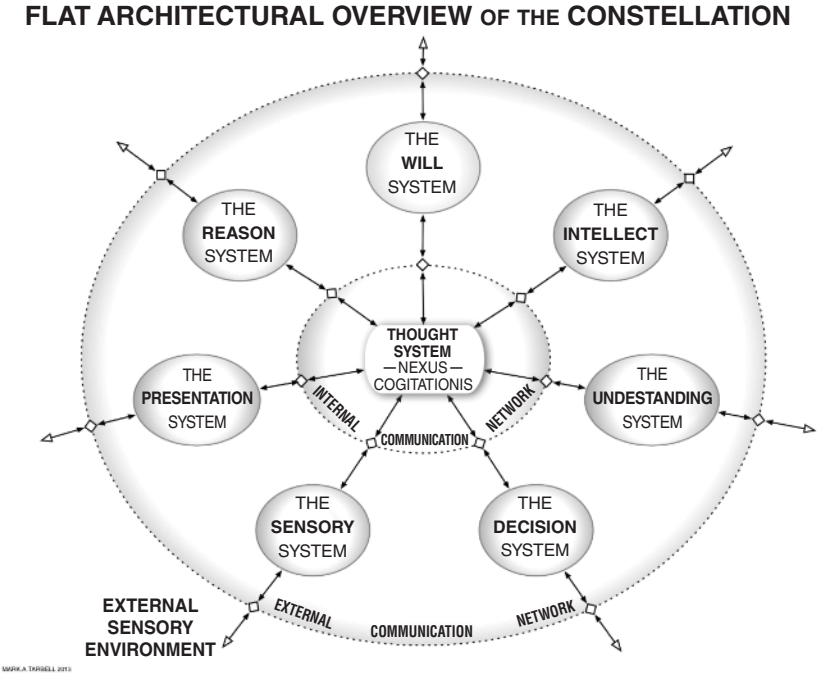

FIGURE 1.1 A 2D flat architectural overview of the autonomous system constellation, showing all systems and their relationships.

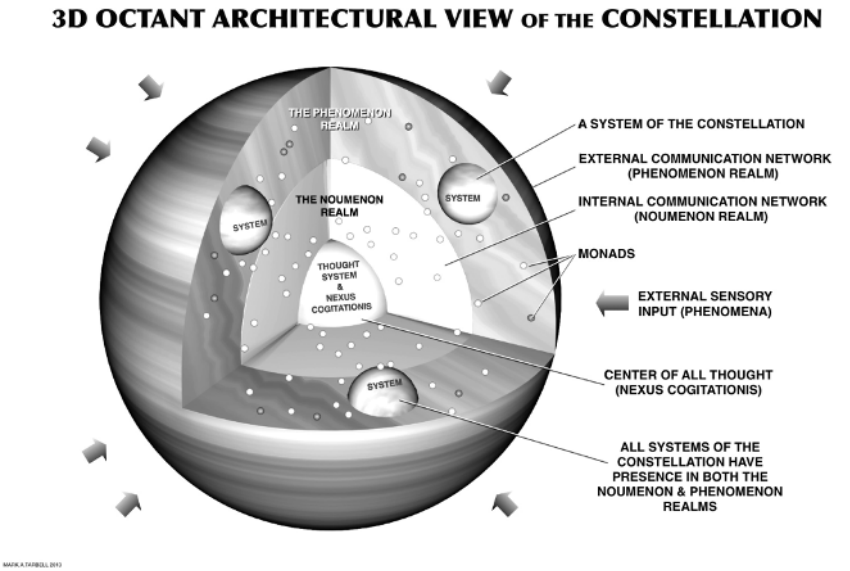

FIGURE 1.2 A 3D octant cutaway architectural view of the autonomous system constellation, showing the structure of the Noumenon and Phenomenon realms with respect to the systems embedded within.

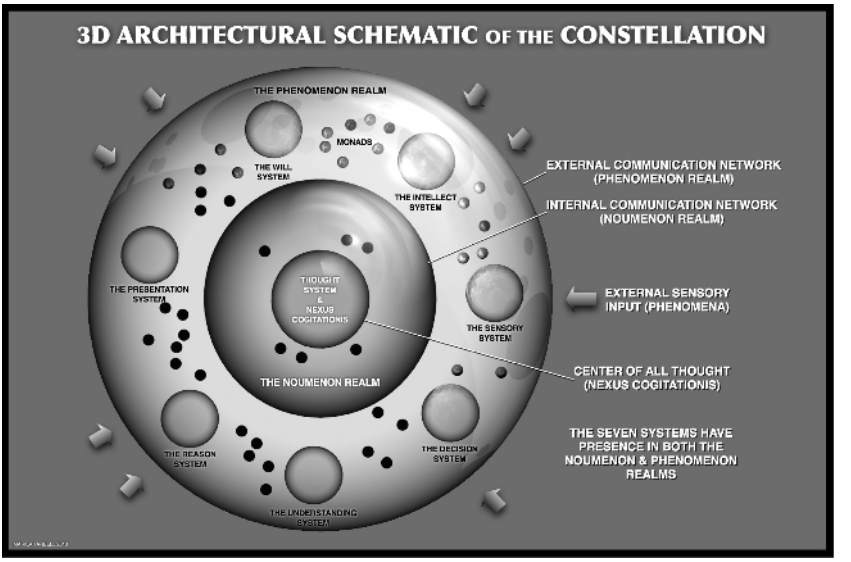

FIGURE 1.3 A 3D architectural schematic of the autonomous system constellation as viewed from the outside, showing all of the systems in the Noumenon and Phenomenon realms.

transmits all data perceptible to the senses, be they facts or occurrence. This high-speed network is the medium that brings into the system constellation all external sensory information. The information from the external sensors represents the varied phenomena of the environment in which the autonomous system exists, as well as the state of the phenomena of the mechanical state of the constellation itself. These Phenomenon data are carried by an uninterrupted and continuous flow of *monads*.[7] The phenomena are presented in the forms of sound, color, temperature, state (of motion), optical/spectral characteristics, and so on.

The next inner sphere represents the internal communication network, or Noumenon network, which transmits the intellectual (thought) perceptions and intuitions between the systems in a natural (human) language. The Thought system is supervised by the *Nexus Cogitationis*, the center of all thought. The Nexus is a necessary system inferred from the material presented by Kant, Hegel, and Schopenhauer in their works, not explicitly mentioned or discussed but implied out of architectural necessity. The Thought system is also orchestrated by the Nexus Cogitationis. This is the architectural network that facilitates the process of thought and gives the autonomous system a sense of being and consciousness, of self and existence. The Thought system is the internal network tightly coupled to all of the systems of the constellation, processing on the order of billions of monadic transactions per second. This enormous volume of data processing is based on dynamic logic in addition to the simpler hierarchical, sequential logic.[8]

1.4.1 The Four Categories of Communication

A brief overview of the four categories of communication transmissions is in order.[9]

- **(a)** The *Monologue*, a one-way simplex transmission of any given system to another given system
- **(b)** The *Dialogue*, a two-way duplex transmission between any two systems
- **(c)** The *Broadcast*, a one-way simplex transmission by any one system to some or all of the systems
- **(d)** The *Conference* transmission, a multiplexed *n*-to-*n* communication. This is a communication mode in which many or all of

> the systems of the constellation participate in problem-solving and consideration of courses of action to be developed to deal with a problem confronting the constellation as a whole. In human terms, this would be considered a discussion or debate.

The Nexus Cogitationis is the constellation's *Konzertmeister*, the communication controller, but also much more. It is here that the process of thinking begins,[10] where all thought activity is monitored, and at times, as with a very disciplined and intelligent human mind, where thinking is orchestrated. It is here that the functions of contemplation, consideration, and self-awareness/self-consciousness take place.

1.5 THE SOFTWARE SYSTEMS COMPRISING THE CONSTELLATION

1.5.1 The Will System

The Will system is a stated design requirement.[11] The Will system is, functionally, the "executive system" of the constellation. It is the driving force of the physical existence of the autonomous system. All living creatures have a Will.

The Will system is the primary system of the mind, and as such, it is dominant in the constellation. In the cognitive sciences, the Will is an object, even considered to be the "thing unto itself."[12]

The Will system is the survival system, including survival of the individual and of the species (accomplishment of the mission, reproduction). It is the system of self-repair of malfunctions and reprogramming, and the system of dominance (to rule, direct, decide, and dominate others of its species, including the other systems within the constellation). The Schopenhauerian concept is that the Will is an object, the "thing unto itself" that holds together all visible and nonvisible elements in a system. This makes logical sense from a software engineering point of view. If the Will system is an object to the architect, then so are the other systems in the constellation. This enables an understanding of the human thought process and allows for its modeling. Another reason for taking advantage of the concept of the "objectivization of the Will" is the famous dictum of Thucydides, "A

compromise is only possible among equals; the powerful will ever extract tribute from the weak, while the weak will ever do the bidding of the strong."[13] In the intelligent and disciplined human mind, there is constant debate over the wanting to do something and the counter-argument of why not to do so. It therefore becomes clear to the systems architect that in the mind of an intelligent and disciplined human being, there are independent and objectivized systems as opposed to systems that simply go along with the dictates of the Will.

To the systems architect's advantage, this is a starting point for design. The Will system as an object is a stated design requirement in that it has been described and researched, dissected and discussed, fought and argued over by some of the finest scientific and mathematical minds in the world.

The primary subsystems of the Will system are the Environment subsystem, the Mission subsystem, the Executive subsystem, the Constellation Repair subsystem, and the Axioms subsystem, which acts as a database connected directly to the Reason system. See Figure 1.4.

The primary internal servers of the Will system are the Noumenon server, the Phenomenon server, and the Axioms server. All of the

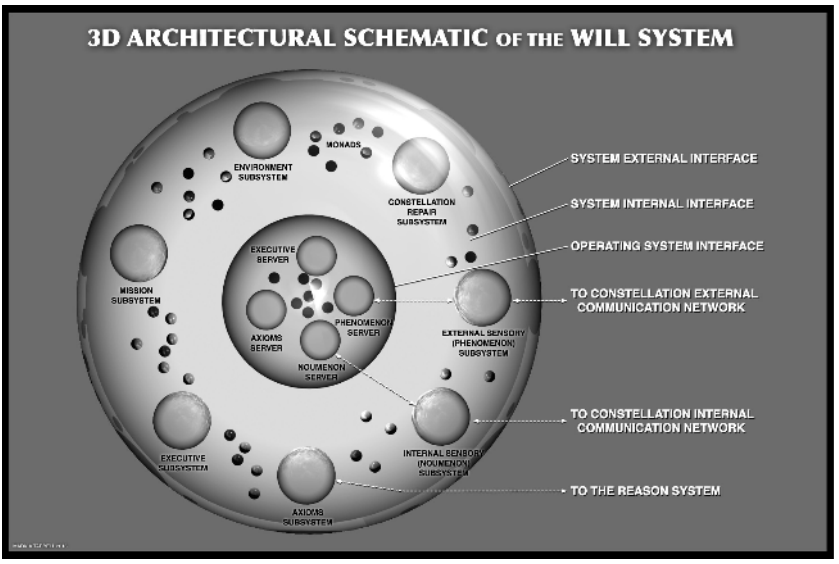

FIGURE 1.4 A 3D architectural schematic of the Will system, showing the internal servers and subsystems.

servers have extensive subfunctions. Consider from the architectural perspective the issue of the Axiom's[14] connection to the Reason system.

1.5.2 The Reason System

The Reason system is a stated requirement.[15] The Reason is described by Immanuel Kant as having two states. The first state is the Practical Reason,[16] and the second state is the Pure Reason.[17] In the functional architecture of the autonomous system's mind, the Reason system is the "conscience" of the mind. In the practical state, it participates not only in both routine and nonroutine operation of the constellation, but as an advisor albeit without executive powers. In the pure state, it is the leader of contemplation and reflection, pondering issues relating to everything important to the constellation.

It has three major subsystems or functional attributes. See Figure 1.5. The first attribute is the Laws subsystem, adherent to the unbreakable laws given by the systems architect or systems engineer to the autonomous system. The laws are the priorities for the protection of

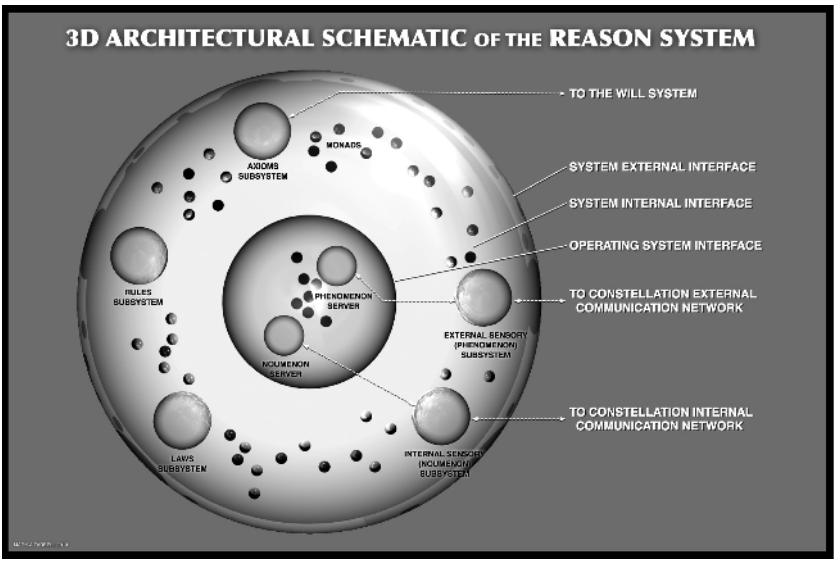

FIGURE 1.5 A 3D architectural schematic of the Reason system, showing the internal servers and subsystems.

the autonomous system and the environment in which it works. These laws are programmed into the constellation and are inviolable.

The second attribute is the Rules subsystem. Rules are not laws; they are guidelines for the effective and efficient operation of the autonomous system. Rules relate to working and learning, and may be modified through input from the other systems in the constellation or by external programming during the design phase of the autonomous system project.

The third attribute is the Axioms subsystem, which allows for a quick reference to summations of complicated rules, generally to avoid making a dangerous mistake.

Once the Reason system is properly programmed, there must be no conflict in the constellation as to following the rules, laws, and axioms for the accomplishment of the mission, especially between the Will system and the Reason system.

The Reason system has three servers: the Noumenon server, the Phenomenon server, and the Axioms server, which is a direct link to the Will system.

1.5.3 The Intellect System

The Intellect system is an implied system. It is addressed by Kant, Hegel, and Schopenhauer more like a function, a subsystem, or a process as opposed to an object of its own. However, it is an architectural necessity to have the Intellect as an object and system equal in standing to the other systems in the constellation, as it plays a critical role and performs the even more critical task of *intellection* in the autonomous system constellation. Intellection is the act or process of exercising the intellect through query and stimulation input, the capacity to acquire and apply knowledge. The Intellect system has the role of being the "librarian" of the autonomous system.

The Intellect system receives, processes, and stores all abstract data received through external sensory input. Abstract data are those data that human beings receive as second-hand information, such as from reading books, listening to lectures, reading technical papers, or observing from a distance. This type of data is often mistaken as "knowledge," but it is not. In human beings, this mistake almost always results in great catastrophe when one assumes that an individual who has mastered abstract data must therefore have knowledge. It is true that once

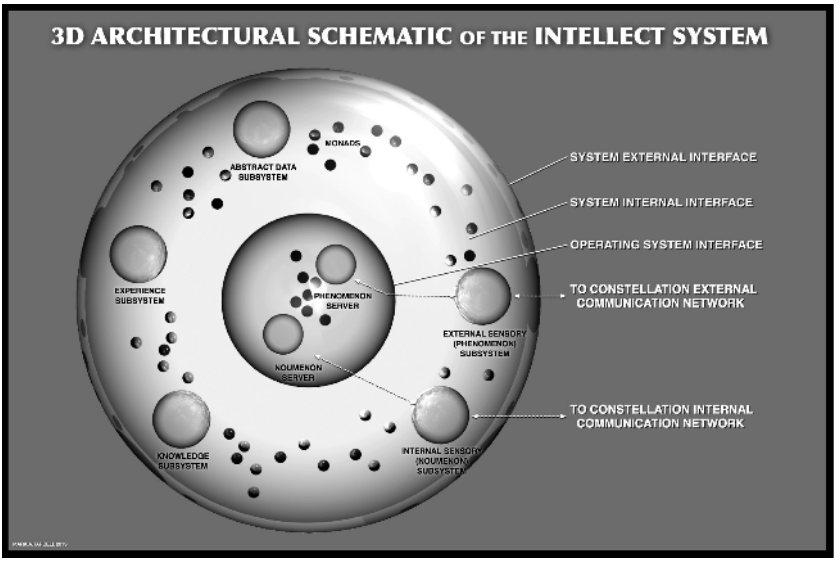

FIGURE 1.6 A 3D architectural schematic of the Intellect system, showing the internal servers and subsystems.

an individual has mastered abstract data, he can achieve a maximum score on an examination based on abstract information; however, unless the data have been validated by experience, the individual has no knowledge in the field. The processing of abstract data and its validation with experience is what results in knowledge.

In addition to the Noumenon and Phenomenon servers, the Intellect system has three major subsystems: the Abstract Data subsystem, the Experience subsystem, and the Knowledge subsystem. See Figure 1.6.

The Abstract Data subsystem acquires, processes, and stores all information gained from secondhand sources.

The Experience subsystem stores experiences in a database-like repository, be they good, bad, useful or not, harmful or beneficial. The abstract data are then validated by experience either in the field or in a laboratory. When the abstract data have been validated with contextual experience, they become knowledge. A sound decision is made first based on knowledge, then on experience, and only rarely on abstract data alone. When the Will system makes a calculated decision, it is based on the knowledge provided by the Intellect system and the rules provided by the Reason system.

The Knowledge subsystem processes abstract information and validates these through experience. This integration of real hands-on experience gained through trial and error to validate an abstract data set is the process of creating real knowledge. For our purposes in the design of an autonomous system and its cognitive functions, anything less than a perfect, correct, timely, and accurate decision is unacceptable. Even if the Will system is good and willing to accept and act on input from the Reason system (e.g., ethical rules, laws, and axioms), if the input from the Intellect system is based on incomplete information (e.g., primarily abstract knowledge), it follows that the decision will be flawed or wrong.

The main servers of the Intellect system are the Noumenon server and the Phenomenon server.

1.5.4 The Presentation System

The Presentation system is a stated and defined system.[18] The Presentation, as a system in the constellation, is the "theater of the mind."

The Presentation system is truly a virtual theater and a systems object with a phenomenal capability of displaying all sensations to the systems of the constellation. It is critically important to the survival of the autonomous system in that it can present the consequences of a decision made by the Will in real time. It has the capability of real-time presentation of one or more courses of action to anything under consideration by the constellation. The courses of action and their consequences, however, depend on the mode (contemplative vs. active) of the process, and include the following considerations:

- The completeness of the knowledge available from the Intellect system
- The rules, laws, and axioms provided by the Reason system
- The urgency of action for a decision, if in an active mode.

The presentation can be via any medium, such as sound, smell, temperature, motion, color, dimension, and size, and includes the sensations felt during a replay of experiences.

When dealing with the systems of the constellation, we are dealing with the mind of the autonomous system, and as such, the Presentation

system is an objective system. The Presentation system is critical in that it can present the consequences of an action based on a decision made *a priori*. If the decision can have destructive consequences, it will play the entire motivation, action, and outcome instantly and thereby warn the autonomous system in the hope of changing the decision to a more positive course of action. If the Presentation is flawed, inhibited, or underdeveloped, it cannot perform as it does in a highly developed human mind.

The Presentation system also has a history database of all previous experiences, both pleasant and unpleasant, with all the surrounding facts bearing on the memory segment, and can replay all variations of the experience. This can manifest itself as contemplation, problem-solving, memory maintenance, or the preparation of sets of valid and invalid references.

In addition to the Noumenon and Phenomenon servers, the main subsystems of the Presentation system are the Viewing subsystem, the Projection subsystem, the Experience subsystem, the Analysis subsystem, the Recall subsystem, and the Contemplation subsystem. See Figure 1.7.

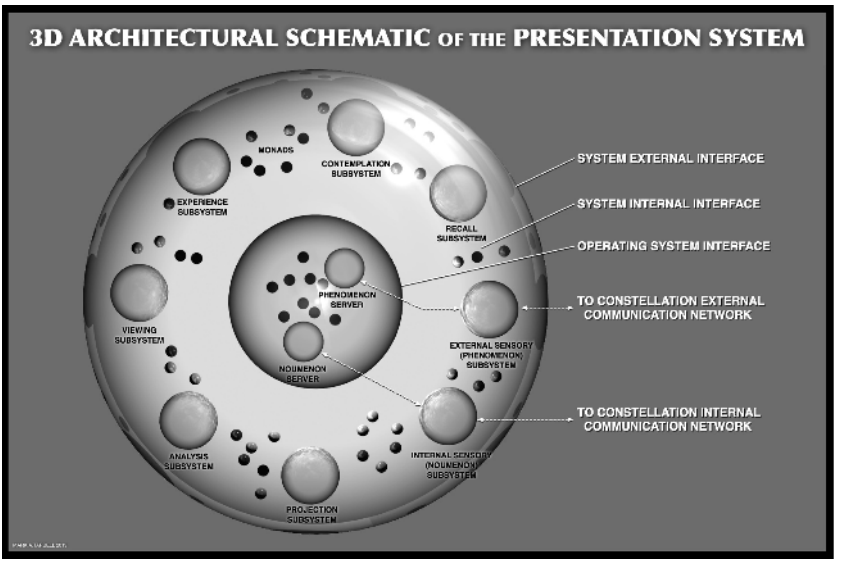

FIGURE 1.7 A 3D architectural schematic of the Presentation system, showing the internal servers and subsystems.

The servers of the Presentation system are the Noumenon server and the Phenomenon server.

1.5.5 The Understanding System

The Understanding system is inferred from the sum of the works used as reference in this book. It is in the Understanding system that the material for thinking is assembled, compiled, and presented to the constellation for review and consensus. See Figure 1.8. The German meaning of the word *Verständnis* includes not only understanding but the functional attributes of cleverness, recognition, and the ability to think clearly and concisely. This capability is missing in many human beings, manifesting itself in rather interesting ways, such as the running of red lights while driving. Thus, when contemplating the implementation process of building the autonomous system, it must be kept in mind by the design team that the Understanding system must not be permitted to make such mistakes. The autonomous system is to have *by design* a superior mind, with not only a well-developed Intellect, Reason, a

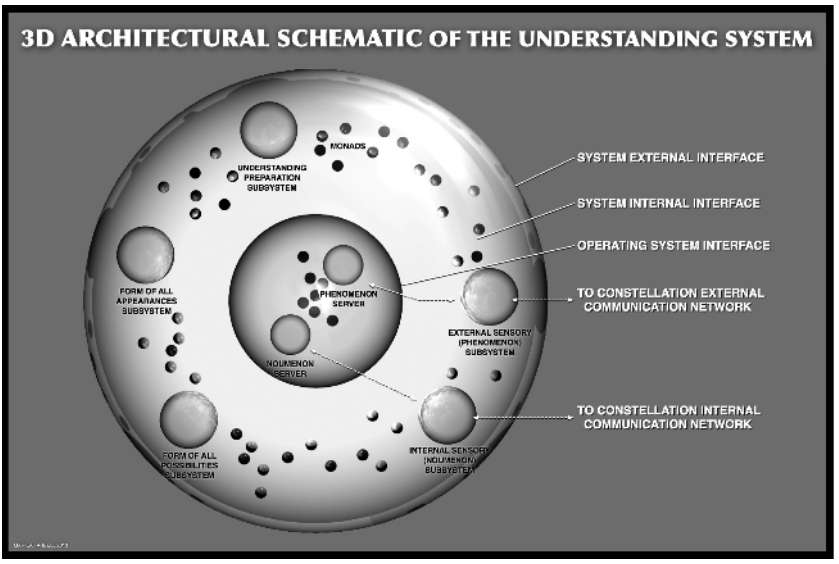

FIGURE 1.8 A 3D architectural schematic of the Understanding system, showing the internal servers and subsystems.

good Will, and a superb Presentation, but a full Understanding of what it must know to survive and to comprehend the mission objectives.

Some of the functional attributes of the Understanding system are the ability to learn (which is a capacity for applied knowledge), and the ability to process abstract data, experience data, as well as knowledge by accessing the Intellect system. Recall that *intellection* is the act or process of exercising the intellect through query and stimulation input; it is the very capacity to acquire and apply knowledge itself.

The main subsystems of the Understanding system are the Form of All Appearances subsystem, the Form of All Possibilities subsystem, and the Understanding Preparation subsystem. See Figure 1.8.

The main servers of the Understanding system are the Noumenon server and the Phenomenon server.

1.5.6 The Sensory System

The Sensory system is a stated and implied system. There can be no self-awareness or self-identity without external sensory information and an awareness of the external environment. This system, as with all of the systems of the constellation, is a design object, and as such, it is of equal standing with the other systems. It receives its external and internal sensory data by means of Phenomenon monads[19] from the sensors placed external to the autonomous system body. It receives the sensory input internal to the body from internal sensors, which monitor the electrical, mechanical, and scientific components and instruments through the Phenomenon monads also.

The subsystems of the Sensory system are the External Sensory (Phenomenon) subsystem, the Internal Sensory (Noumenon) subsystem, the Propulsion, Motion, and Manipulation subsystem, the Standards and Limits subsystem, and the Autonomous System State subsystem. See Figure 1.9.

The major servers of the Sensory system are the Noumenon server and the Phenomenon server.

1.5.7 The Decision System

The Decision system is a stated and defined system. This system is described both functionally and architecturally in great detail by Immanuel Kant.[20] It is both a system object as well as a complex architectural systems process. Ironically, from the perspective of Kant's

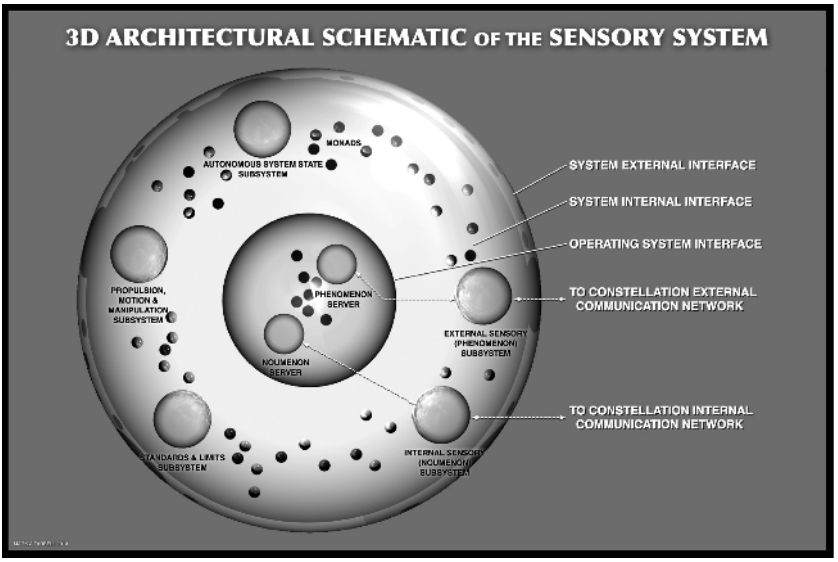

FIGURE 1.9 A 3D architectural schematic of the Sensory system, showing the internal servers and subsystems.

monumental work, modern computer-based "expert systems" and "decision systems" are so primitive as to be almost medieval. Modern decision systems are hierarchical and sequential, using little more than Boolean logic with a few algorithmic extensions. Kant's decision system utilizes *dynamic logic*, going beyond Aristotle.

The Decision system is therefore defined as a systems object of indispensable value. The German word *Urteilskraft* from the point of view of a systems architect and systems engineer has a broad meaning. *Urteil* in English means verdict, judgment, decision, view, and opinion; *Kraft* means strength, power, force, energy, efficacy, and validity. The Decision system therefore is not only the system where decisions are formulated and manufactured, but the system where the power and energy reside to *make* a decision, and a right one at that. For human beings, making a "correct" decision is not always the "right" decision. This is because the right decision is also dependent on ethical considerations.

As stated in the above, one functional aspect of making a decision is the energy and power required to do so. In human terms, especially in computer science software-intensive projects, we often encounter

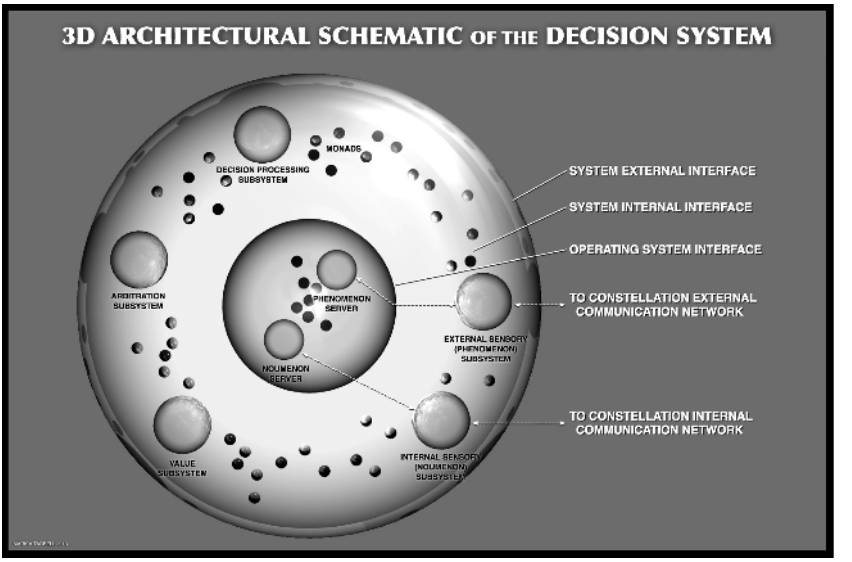

FIGURE 1.10 A 3D architectural schematic of the Decision system, showing the internal servers and subsystems.

people in engineering and management who "can't make a decision." From the perspective of an engineer on a project, if a manager or systems engineer can't make a decision, the consequences are terrible. Sometimes, spacecraft are lost or ships are sunk, all as a direct result of the inability to make a right decision.

Thus, the Decision system in the autonomous system constellation represents the "operations officer." It assembles all relevant data from the systems of the constellation and prepares a number of prioritized courses of action with the Will system.

The main subsystems of the Decision system are the Arbitration subsystem, the Value subsystem, and the Decision Processing subsystem. See Figure 1.10.

The major servers of the Decision system are the Noumenon server and the Presentation server.

1.5.8 The Thought System: Nexus Cogitationis

As a stated and defined system, and the ultimate object of the autonomous system constellation, the Thought system is the main purpose of

this volume, that is, to explain how thinking works from a software architectural perspective. The Thought system is described as the internal communications of the autonomous system, showing the architecture of how the autonomous system will work once development starts.

The model used for the autonomous system is, of course, the *human* thought system. Indeed, there can be no other model for such a system because only human beings can describe and articulate how we think; only we as humans know *with understanding* how to drive an automobile or fly an aircraft. We also acknowledge that many of us as human beings cannot think or have otherwise impaired thought systems.

As a case in point, for the purposes of an autonomous system, we cannot model how a rat thinks because we cannot hold a conversation with a rat to discern more clearly how it processes data; we can only infer from observation.[21] This conscious inferential reasoning is unique only to a well-developed human mind. The idea of using the rat as the model for an autonomous system's cognitive process is not practical, since doing so would be based on empirical data only. The human mind is accessible through tests and dialogues held with those who have intelligent, well-developed minds.

This idea, now developed into a concept, has its origins in the thought experiments or *Gedankenexperimente* conducted by Immanuel Kant. An autonomous system that can exist on its own without human involvement must have a self-identity and a sense of being. G.F.W. Hegel addresses this in his work and experimental research.[22] A sense of being cannot exist without the consciousness of the existence of an external environment. This implies an ability to contemplate, reason, form judgments, make decisions, learn new things, act and do, and of course communicate with other intelligent beings. Thus, the Thought system must be simultaneously a stated, implied, and derived system object.

We are concerned here mainly with the functioning, operation, and structure of the thought process. Internal communication within the mind is carried by monads among the systems of the constellation in the form of thought-logic elements called *Noumena*, and the network of intellectual data flow operates in the forms of Monologue, Dialogue, Broadcast, and Conference transmission types. The human thought system is dynamic in character and is represented in the mathematical form of integral and differential calculus.[23] This is the dynamic logic of the mind, and it is Hegel who formalized it.

The Thought system is termed the *Nexus Cogitationis*, the center or hub of all thought. The Nexus Cogitationis monitors all of the channels of communication, including the Phenomenon (external communications), which requires its attention, and is involved when clarification is needed.

The Thought system contains within itself the primary communication engine of the autonomous system, for communication both within itself (among the systems) and with the world outside of the constellation. It can communicate in the human language it has learned through programming or on its own.

The Thought system serves as the central data distribution system between the systems of the constellation. It is an unlimited *n*-processor function itself, and can expand processor utilization/capacity on demand in accordance with the requirements and effort put into expansion in hardware and software, such as when the processing requirements of a particular system exceed the existing hardware and communications capability.

This expansion of the thinking power through the Thought system can be controlled and allocated according to the availability of processing space. Processing space in human beings for "rational thinking" can only be built through much effort, discipline, and practice. In short, it takes a willful determination and diligence to learn how to think in the human model. In the autonomous system, this capability is designed and programmed in by the design team.

All external and internal data communications are processed and monitored by the Thought system. Demands from sensors are received and passed on to the Sensory system and the Understanding system as a safeguard against missed sensor communications and commands.

In addition to the ubiquitous Noumenon and Phenomenon subsystems, the main subsystems of the Thought system are the Monologue subsystem, the Dialogue subsystem, the Broadcast subsystem, and the Conference subsystem. Each of these subsystems has its own corresponding server placed in the Nexus Cogitationis. The communication-related subsystems include the Fault Monitoring subsystem, the Command and Demand subsystem, and the Communication subsystem. See Figure 1.11.

The major servers of the Thought system are all communication-related: the Noumenon and Phenomenon servers, the Monologue and Dialogue subsystems, and the Broadcast and Conference servers. Note

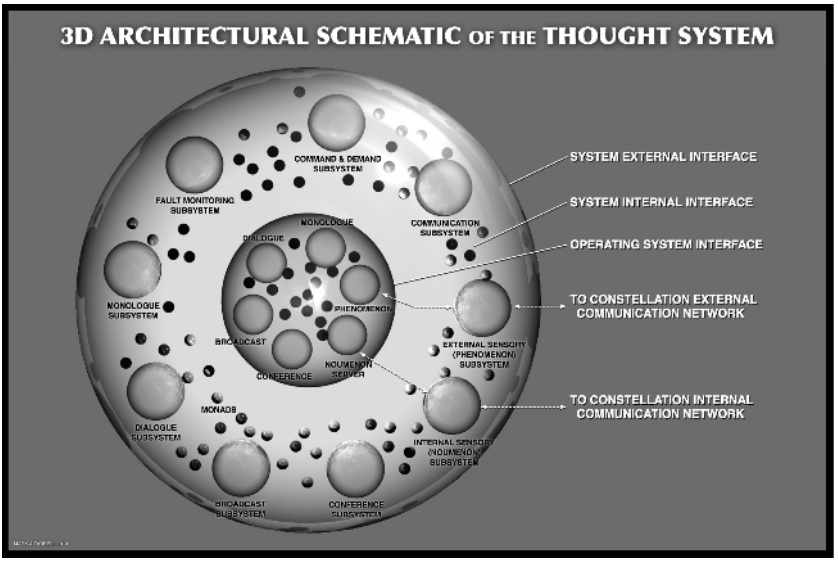

FIGURE 1.11 A 3D architectural schematic of the Thought system, showing the internal servers and subsystems.

that the Noumenon and Phenomenon servers drive "streaming networks" that flow steadily without stop-and-go. The internal information elements are carried and formulated as *Noumena*—thought fragments—by Noumenon monads, whereas the Phenomenon monads carry what is akin to sensual data in humans, and sensory data in mechanical devices.