# General Systems Theory:
# A Knowledge Domain in Engineering Systems

Fleming Ray
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## 1. Introduction

General Systems Theory (GST) arose out of several disciplines, including biology, mathematics, philosophy, and the social sciences. As the discipline has emerged, its goal has changed. Von Bertalanffy began thinking about GST in the 1930s, but did not articulate his vision until 1954 at the AAAS conference. Originally, his goal was to get biologically minded scientists to consider their work from a holistic perspective. As his thoughts evolved, the goal became to construct a mechanism for reducing duplication of theoretical effort in the sciences. It was proposed that GST could serve as a unifying theoretical construct for all of the sciences. To this end, mathematicians and philosophers became engaged in creating a rigorous theory. This paper traces the evolution of GST, including its institutional history, and its current areas of use.

## 2. Definition

General Systems Theory arose out of the efforts of researchers who were searching for homologies between work in the biological, physical, and social sciences. Different definitions of GST have propagated, depending upon the background and focus of the researcher. According to Klir [1972], "General Systems Theory in the broadest sense refers to a collection of general concepts, principles, tools, problems, methods, and techniques associated with systems." In this case, a system is "an arrangement of certain components so interrelated as to form a whole." This systems approach arose in contrast to the Newtonian method of separating an object into its component parts and trying to understand the behavior of the object by understanding the properties of the individual parts while ignoring their interactions. A related definition is given by Miller [1978], "General systems theory is a set of related definitions, assumptions, and propositions which deal with reality as an integrated hierarchy of organizations of matter and energy."

The mathematics of General Systems Theory is based largely upon set theory. Using these tools, formal system components and their relationships can be defined. Basic concepts are introduced axiomatically, and the system's properties and behavior can be investigated in a precise manner. General Systems Theory is particularly applicable to systems with goal seeking behavior; biological and social systems are the primary domains of such goal seeking behavior. Although precise, the model of the system often has to be simplified to high level of abstraction to make the computations tractable.

## 3. Institutional History and Development of GST

General Systems Theory, along with other accompanying theories of systems such as cybernetics and control theory, came to prominence after World War II. There are multiple reasons for such concurrent emergence; important contributing factors included the creation of new systems tools, the presence of important work by multiple investigators in cybernetics, control theory, information theory and General Systems Theory, and the presence of computational capacity.

General Systems Theory arose in the 1950s when other mathematically oriented systems techniques were also popular. Von Bertalanffy began thinking of General Systems Theory in the 1930s, but due to the unfavorable intellectual climate, did not air his ideas until much later [von Bertalanffy, 1968]. In 1954, Boulding, an economist, Rapoport, a biomathematician, Gerard, a physiologist, and von Bertalanffy, a biologist, founded the Society for General Systems Theory at the annual meeting of the American Association for the Advancement of Science (AAAS). Later, the organization changed its name to the Society for General Systems Research. The journal *General Systems* was launched at the same time to serve as the organ for the society.

The purpose of the society read as follows:

> The Society for General Systems Research was organized in 1954 to further the development of theoretical systems which are applicable to more than one of the traditional departments of knowledge. Major functions are to: (1) investigate the isomorphy of concepts, laws, and models in various fields, and to help in useful transfers from one field to another; (2) encourage the development of adequate theoretical models in the fields which lack them; (3) minimize the duplication of theoretical effort in different fields; (4) promote the unity of science through improving communication among specialists. [von Bertalanffy, 1968]

Initial criticisms of general systems theory included the concern that GST was trivial, false and misleading, or unsound philosophically and methodologically. The concern over the trivial nature of GST arose because some critics thought GST only provided insights analogous to the idea that exponential decay could be used to describe phenomena in multiple fields. In reality, the aim of GST was to provide a formal logical structure grounded in set theory to describe the relationship between different parts of a system.

The concern over the false and misleading nature of GST arose because some critics thought GST made false analogies such as equating organisms with societies. In fact, von Bertalanffy and others were aware of the intellectual and practical dangers of making false analogies. To address this concern, GST focused on drawing rigorous homologies between disciplines. Additionally von Bertalanffy expressed his belief that "Man is not only a political animal; he is, before and above all, an individual. The real values of humanity are not those which it shares with biological entities, the function of an organism or a community or animals, but those which stem from the individual mind." [von Bertalanffy, 1968].

Finally, the concern over the philosophical and methodological fallacies largely arose because researchers in individual fields were concerned that researchers would be distracted from the real problems within their field. von Bertalanffy and others were quick to point out that GST could help solve those problems by providing a theoretical framework with which to attack unsolved disciplinary problems. The goal of GST was to avoid duplicating efforts to define systems that were needed to study biological and social systems.

## 4. Relationship with other domains

GST is one of the more theoretical domains in engineering systems. von Bertalanffy [1968] includes cybernetics, information theory, game theory, decision theory, topology, and factor analysis as complementary scientific domains. Areas of engineering application include systems engineering, operations research, and human engineering. Human engineering includes design for human factors and ergonomics.

In some ways cybernetics and GST are very similar since they both are used to model communication and control processes. Some of the political science work by Deutsch (1966) builds on these concepts of communication and control in a systems context. Rapoport (1960), although dealing largely with the theory of games to analyze conflicts, acknowledges the many frames of reference - psychological, sociological, and ethical - which are needed to analyze conflict. In so doing, he acknowledges his indebtedness to Boulding (1956), one of the early contributors to GST.

## 5. Applications and Research

Current uses of General Systems Theory are found in developing better models of human-machine interaction to improve medical diagnostics [Majumder, 2000]. Additionally, GST is used to structure environmental investigations [Pykh, 2000]. GST is not cited often in the most predominant journals, such as *Science* and *Nature*, therefore indicating it is still used by a small group of people. Additionally, mathematicians are continuing to work on unsolved problems in set-theoretic General Systems Theory [Lin, 1997].

## 6. Evaluation of GST

In the most literal sense of fulfilling the goals which were stated upon the founding of the Society for General Systems Theory, GST has not succeeded. General Systems Theory has not succeeded in providing a unifying framework for science, and it is difficult to measure whether people are duplicating each other's work less.

Evaluating the direct impact of GST is difficult since the people working on GST also were involved with other systems initiatives which changed the way some people practiced science. Since the 1950s, ecological awareness has arisen, and there were researchers who were involved in GST and ecology [Boulding, 1978]; however, determining the impact of GST on ecology is difficult. For example, the presence of large environmental disasters provided motivation for people to think about systems while the presence of tools such as GST made it possible to do productive work. It is difficult to argue that it was the tool itself (GST) which caused the interest in ecological systems to rise. In the opinion of Anatol Rapoport, "Awareness of the interrelatedness of everything to everything else is the most important 'practical' result [of GST]."

Going forward, General Systems Theory will be used by generalized experts, i.e. people who are grounded in a discipline yet who also understand the formalism of General Systems Theory.

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