Far from Analogies: How Boyd Used Gödel's Theorem, Heisenberg's Uncertainty Principle, and the Second Law of Thermodynamics

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[Note: This is a draft of a paper originally written as the introduction to a chapter in a proposed book. Although I haven't included a "References" section, the citations should be familiar, with the possible exception of Richard Feynman's *The Character of Physical Law* (1965) — CR]

Boyd mentions one or more of the three principles in five of his seven works completed after he retired from the United States Air Force in 1975:

	Gödel's Theorem	Heisenberg's Uncertainty Principle	Second Law of Thermodynamics
Destruction and Creation	pp. 4-7	pp. 4-7	pp. 6, 7
New Conception for Air-Air Combat	pp. 19, 21	pp. 19, 21	pp. 19, 21
Patterns of Conflict	none	none	none
Organic Design for Command and Control	p. 20	p. 20	p. 20
Strategic Game of ? and ?	pp. 23, 28, 39, 40, 42, 43	pp. 23, 28, 39, 40, 42, 43	pp. 23, 28, 39, 40, 42, 43
Conceptual Spiral	pp. 10, 14, 32	pp. 10, 32	pp. 9, 32
The Essence of Winning and Losing	none	none	none

Although Boyd first mentions the three principles in *New Conception for Air-Air Combat*, which preceded "Destruction and Creation" by about one month (Coram, 322), it is in the latter paper that Boyd gives his most detailed arguments for employing the concepts (Osinga, 98).

The system that he is investigating, using these principles as well as his own logical constructions, is one's set of concepts for representing reality and the match-up of those concepts with reality. He uses the three principles in at least three ways:

- To lend credibility to the conclusion that we should, at some point, "anticipate a mismatch between phenomena observation and concept description of that observation." (D&C, 4)

- As a source of uncertainty or inconsistency undermining our ability to determine the degree to which our system of concepts match up with reality (D&C 6; Osinga 118, 263)

- To "support the idea that any inward-oriented and continued effort to improve the match-up of concept with observed reality will only increase the degree of mismatch." (D&C 6)

The language that he uses shows that far from reasoning by analogy, he is applying the three principles directly to the system in question, that is, to the set of concepts for representing reality and the match-up of those concepts with reality (D&C p. 5). For example, he summarizes his discussion of the three principles with the following conclusion:

> According to Gödel we cannot—in general—determine the consistency, hence the character or nature, of an abstract system within itself. According to Heisenberg and the Second Law of Thermodynamics any attempt to do so in the real world will expose uncertainty and generate disorder. (D&C 6)

The question of how well a person's or group's concepts for representing reality match up with that reality and the consequences of how one determines the degree of match-up (consistency) are issues in the social sciences, including the study of strategy. Before considering whether Boyd's use of these three principles is valid in the social sciences, it is important to note which form of each principle he is employing because, as Feynman (1963) observed, science often encounters "wide principles that sweep across all the laws, ... [that] often extend beyond the range of their deduction."

In the case of Gödel, it is simply that an abstract system of basic complexity, which could reasonably include the system of concepts for representing reality, must be incomplete and its consistency cannot be demonstrated within that system. For Heisenberg, although he quotes the famous uncertainty equation of quantum mechanics, which most certainly does not pertain to social systems, he cites Heisenberg to conclude that the equation "implicitly depends upon the indeterminate presence and influence of an observer" (D&C 6; Osinga, 98, 182), and this is a conclusion which could pertain to the social sciences.

Finally, for the Second Law, it is important to note that Boyd does not attempt to apply the equations of thermodynamics to social systems. Instead, he cites several sources that justify formulating the law as requiring "that all observed natural processes generate entropy," and that "From this law it follows that entropy must increase in any closed system—or, for that matter, in any system that cannot communicate in an ordered fashion with other systems or environments external to itself." (D&C, 6; Osinga 182). Boyd applies that formulation directly to the system of concepts for representing reality:

> Accordingly, whenever we attempt to do work or take action inside such a system—a concept and its match-up with reality—we should anticipate an increase in entropy hence an increase in confusion and disorder. (D&C 6).

This paragraph also links what has until this point been an abstract discussion of epistemology to the social sciences in a direct way, namely the activities taken by people in groups and the effects of those activities.

The three principles are also cited numerous times in the *Discourse* outside of "Destruction and Creation." Osinga (117) suggests that Boyd is developing the theme that inwardly oriented efforts to improve match up of concept with reality will cause Gödel and the Second Law to, at some point, "kick in." In *Organic Design*, he begins this process by expanding on the notion of "centers of gravity," a strategic concept introduced by the Prussian general and strategist Clausewitz (1832):

> Now, by applying the ideas of Darwin, the Second Law, Heisenberg, and Gödel to Clausewitz one can see that: He who can generate many non-cooperative centers of gravity magnifies friction. Why? Many non-cooperative centers of gravity within a system restrict interaction and adaptability of system with its surroundings, thereby leading to a focus inward (i.e., within itself), which in turn generates confusion and disorder, which impedes vigorous or directed activity, hence, by definition, magnifies friction or entropy. (OD, 20)

The ultimate effect of such an inward focus would be "to deny the adversary an opportunity to cope with events as they unfold." (OD, 23). In his next presentation, *Strategic Game of ? and ?*, he continues this development to bring in the external environment:

> Gödel's Incompleteness Theorems, Heisenberg's Uncertainty Principle, and the Second Law of Thermodynamics, all taken together, show that we cannot determine the character or nature of a system within itself. Moreover, attempts to do so lead to confusion and disorder—mental as well as physical. Point: We need an external environment, or outside world, to define ourselves and maintain organic integrity, otherwise we experience dissolution/disintegration— i.e., we come unglued. (SG, 28)

Hammond (120) observes that Boyd's ultimate purpose is to apply the principles to the practice of strategy, "how to compete successfully, and how to adapt and survive." Boyd concludes this line of development with an "illuminating example" that applies the three

principles to the practice of military strategy. He asks a rhetorical question, "Taken altogether, what do Gödel, Heisenberg, the Second Law of Thermodynamics, and the tests of the YF-16/YF-17 say?" to which he answers:

> The ability to operate at a faster tempo or rhythm than an adversary enables one to fold adversary back inside himself so that he can neither appreciate nor keep-up with what's going on. He will become disoriented or confused; which suggests that unless such menacing pressure is relieved, adversary will experience various combinations of uncertainty, doubt, confusion, self-deception, indecision, fear, panic, discouragement, despair, etc., which will further disorient or twist his mental images/impressions of what's happening; thereby disrupt his mental/physical maneuvers for dealing with such a menace; thereby overload his mental/physical capacity to adapt or endure; thereby collapse his ability to carry on.

Again, these are clearly conclusions in the social sciences. The question of validity will depend in large part on how one interprets "all taken together" and "say." Note that he is not claiming that his conclusions follow as mathematical proofs from any one of these.

The last citation occurs in *Conceptual Spiral*, where he returns to epistemology, the subject of "Destruction and Creation." Of the three principles, he cites only Gödel to conclude that:

> Taken together, the theorems associated with Gödel, Lowenheim & Skolem, Tarski, Church, Turing, Chaitin, and others reveal that not only do the statements representing a theoretical system for explaining some aspect of reality explain that reality inadequately or incompletely but, like it or not, these statements spill out beyond any one system and do so in unpredictable ways;

> Or conversely,

> These theorems reveal that we can neither predict the future migration and evolution of these statements nor just confine them to any one system nor suggest that they fully embrace any such system. (CS, 14)

In addition to supporting the conclusion that "mismatches will arise," which Boyd first states in "Destruction and Creation" (Osinga 263), it also suggests Boyd's own answer to those who criticize his use of principles originally from mathematical logic and physics to the social sciences: "these statements spill out beyond any one system and do so in unpredictable ways."