ProHEAL: On a Nearly Forgotten Development of Altshuller's TRIZ

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Abstract

The first German translation of Altshuller's work (1973) was followed up by the development of a unique version of the theory in the GDR in the late 1980s, the *Guidelines for Developing and Resolving Problems in Invention* (ProHEAL). The crucial difference between ProHEAL and ARIZ can be seen in their respective starting points. The ARIZ begins with a problem that is in some way given (either as an administrative contradiction or deduced from the laws of technical evolution), which then has to be turned into a task for inventors. In contrast, ProHEAL includes an additional step, the analysis of social need. Thus, the theory's founders developed a systematic method for analyzing the criteria a technical solution has to meet in order to fulfill a specific social need. Concrete parameters can be deduced from the results of this analysis which in turn allow the inventor to formulate inventive tasks on purpose. As a consequence, the direction that technological development takes depends on this analysis and thus on how social needs are determined. It will be shown that because of this shift in perspective, ProHEAL might be seen as a further step in the development of TRIZ. To this end, the tradition of dialectical logic, to which TRIZ and ProHEAL belong, will be traced back to its very origin, namely Hegel's *Science of Logic*. The reflection on the immanent development of Altshuller's TRIZ will not only show that the development of TRIZ was approximating gradually the essential features of Hegel's dialectical logic, but also that ProHEAL can be seen a further step into this direction. It not only takes the history of the technical system and its further development into account, but also the history of social need and the development of society. Technological development is thus correlated with society's development and can no longer be considered as an end in itself. By providing the conceptual means for operationalizing this dependency, it becomes not only possible to plan invention (TRIZ), but also to guide it (ProHEAL) in a particular direction in accordance with the analysis of social need.

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1) Introduction

The paper intends to introduce the reader to the so-called *Guidelines for Developing and Resolving Problems in Invention* (ProHEAL), which can be viewed as a nearly forgotten development of Altshuller's theory of inventive problem solving (TRIZ). However, before turning to the relation between TRIZ and ProHEAL, I would like to take a step back and take a short overview of the tradition of dialectical logic, to which TRIZ and ProHEAL belong. This will help us gain a better understanding of both the historical development of TRIZ and its developmental potentials. I will show that the systematic and historical origins of TRIZ and the entire tradition that developed out of it can be traced back to Hegel's *Science of Logic*. In order to show the systematical dependencies, I will develop the essential logical considerations that underlie Hegel's logic by analyzing the original logical problem that Hegel tempted to solve. According to my interpretation, Hegel's *Science of Logic* was inspired by and designed as the solution of some problems raised by Kant's *Critique of Pure Reason* and its underlying *Transcendental Logic*.

For this reason, I will begin with an analysis of Kant's approach to logic (section 2). This will then lead me to work out the problems that it gave rise to, which were then tackled by Hegel's *Science of Logic* and its underlying *dialectical method* (section 3). Following this systematic discussion, I will then turn to the historical dependency of Altshuller's TRIZ on Hegel's logic (section 4). After that, I will recapitulate how Altshuller himself views the developmental steps of his theory (section 5), which again help demonstrate its systematic dependency on Hegel's dialectical logic. Finally, I will discuss the crucial difference between TRIZ and ProHEAL (section 6), showing in section 7 that, from the perspective of both Hegel's *Science of Logic* and Altshuller's TRIZ itself, the ProHEAL can be viewed as a further development of Altshuller's TRIZ.

2 Kant's Conception of Logic

2.1) Why Kant Distinguishes between Two Sub-Systems of Cognition – Thinking and Sensibility

In his Critique of Pure Reason (CPR), Kant (1956) tries to develop an adequate account of *theoretical reason*, i.e. theoretical rationality (as opposed to *practical reason*). According to Kant, the modus operandi of theoretical reason is rational thinking. Logic represents the normative and formal laws of rational thinking. More precisely, the science called logic lays out how we ought to think in order to think rationally.

Kantian logic, however, was conceived of as a formal science in the Aristotelian sense. This means that it abstracts from the specific content of the terms used in judgements and inferences in order to consider the form of the respective judgements and inferences alone. As a consequence, the content must come from another source. Thinking logically thus does not imply thinking something true, because from the Kantian perspective, truth is not exclusively a matter of making logically correct inferences. Rather, it depends on the adequacy of the content of the judgement and its subject, i.e. the object being judged. For this reason, logic can only provide a negative criterion for truth. To respect its rules prevents us from thinking irrationally. However, it cannot guarantee that we think truthfully.

As a consequence of this line of reasoning, thinking rationally means thinking logically and vice versa. However, it does not mean thinking truthfully, because truthful thinking requires more. In the Kantian framework, finite rational beings like us require both rational thinking and the capacity of sensibility in order to be able to think something true. For without sensibility, finite beings could not come into contact with the objects being judged, and the very truthfulness of these judgements depends on such objects. Thus, in order to understand truthful thinking we need to understand both rational thinking, which is the subject of the science called logic, and sensibility, which is the subject of aesthetics.

2.2) Kant’s Invention of Transcendental Idealism as an Attempt to Tackle the Problem of Humean Skepticism

The conviction that the cognition of something true depends on both thinking and sensibility follows from an empiricist conception of cognition. According to this conception, truth can only be found in experience. Kant inherited this conception from David Hume and tried to show that the latter’s skepticism of the truth of judgements of cause and effect could be turned into a version of rationalism.

Building on Hume’s assumptions, Kant tried to show that we would have no experiences at all if we didn’t have the forms of rational thinking, i.e. the forms of logic. Kant argues that if we can demonstrate that the forms of rational thinking (e.g. reasoning in terms of hypothetical “if, then” relations) are necessary for the possibility of having experience at all, our experience must be rationally structured to the extent to which these rational forms are required. In a word, the Kantian analysis shows that rational thought is required for experiencing objects as objects. As a consequence of this line of reasoning, he concludes that objects of experience have to conform to the rational structure of our thoughts (at least to the extent to which these structures are necessary for the possibility of the experience of any objects).

Because of this relation between general subjective rational structures and objects of our experience, Kant thought that we should look to the experiencing subject, and not to the object experienced, when trying to analyze the structures necessary for the possibility of experiencing objects. In this way, Kant argues, we can discover the necessary requirements objects have to meet in order to become objects of our possible experience. This is the underlying idea of the Kantian version of idealism. Since the way of reasoning in terms of necessary subjective conditions of possible experience is called transcendental reasoning, Kantian idealism is called *transcendental idealism* (TI). According to Kant, TI is an alternative to Humean skepticism, although it is based on a similar conception of cognition.

Kant himself compares his shift in perspective to the Copernican Revolution, i.e. to the shift from a geocentric to a heliocentric view of the solar system. Instead of subscribing to the view that the Sun revolves around the Earth, the Sun is placed in the center and the Earth revolves around the Sun. It is a well-known fact that this shift in perspective, which, by the way, can be seen as an application of Altshuller’s 13th principle,[2] made it much easier to understand the movement of the planets and the functioning of the solar system. Analogously, the Kantian shift is supposed to make the necessary conditions of objectivity intelligible by focusing on the experiencing subject (and thus by doing epistemology, i.e. studying the features of cognition) instead of studying the objects themselves.

While the Copernican shift led to the heliocentric worldview, the Kantian one led to the invention of Transcendental Idealism. It stands at the very beginning of the tradition called *German Idealism*, which, in my opinion, reached its apex in Hegel's philosophy. This Hegelian idealism, and particularly its theoretical kernel, the so-called *Science of Logic*, itself led to a new philosophical tradition, namely the tradition of dialectics, to which Altshuller's TRIZ belongs. This dialectical tradition is already present in Kant's *Critique of Pure Reason* (CPR), but the form it takes there is, at least from a Hegelian perspective, unsatisfying.

In the following we will have to take a closer look at Kant's version of TI in order to get a better understanding of the Hegelian dialectical tradition, which emerged as a solution of some of the CPR's problems.

2.3) Kant's Transcendental Logic – The Logic of Truth

The largest section of Kant's CPR is the so-called *Transcendental Doctrine of Elements*. This doctrine falls into two parts, the *Transcendental Aesthetic* and the *Transcendental Logic*. The Transcendental Logic falls again into two parts, the *Transcendental Analytic* and the *Transcendental Dialectic.*

As outlined above, Kant claimed that cognition depends on two sources: sensibility and understanding, which allows us to think. In the *Transcendental Aesthetic*, the subjective conditions necessary for the possibility of experience are analyzed. More precisely, they are analyzed to the degree that they constitute sensibility in general, no matter who the experiencing subject is, how it is physically shaped or when, where, what and under which circumstances it has its experiences. This inquiry leads Kant to the so-called pure forms of intuition: space and time.

[2] "Do it in reverse. [...] b. Make the moveable part of an object, or outside environment, stationary – and the stationary part moveable" (Altshuller, 1998, 49).

The analytical part of the *Transcendental Logic* is first and foremost concerned with an analysis of the understanding. This analysis leads Kant to the pure forms of the understanding – Kant's so-called forms of general logic. In the further course of Kant's text, these logical forms are related to the pure forms of intuition, which makes it possible for us to grasp the way they interact in order to make cognition possible *a priori* – as we have already seen, cognition requires both sensibility and understanding.

Taken together, the analytic part of the *Transcendental Logic* and the *Transcendental Aesthetic* make up the analysis of the way cognition functions according to Kant. In other words, they are sub-systems of what Kant considers the system of cognition of finite beings to be. For this reason, I will refer to these two sections as the *analytic part of the CPR*, since this part intends to give an analysis of the functionality of the system of cognition of finite beings to the extent that it is a condition of possibility of objective experiences. As for the second part of the Transcendental Logic, the so-called *Transcendental Dialectic*, I will refer to it as *dialectical part of the CPR*.

Roughly speaking, the analytic part of the CPR gives description of how the Kantian system of cognition functions. In contrast, the dialectical part of the CPR spells out the contradictions that necessarily occur when one of its sub-systems, the understanding, is applied outside of the territory of the proper functioning of the system of cognition as a whole. Kant calls the territory demarcated by the proper functioning of our system of cognition the *land of truth*, referring to it as an *island* surrounded by a wide and stormy ocean full of fog-banks etc. If the understanding is completely separated from sensibility, it enters the territory of illusions that surrounds the land of truth, like a mariner venturing on the ocean and getting fooled by taking fog-banks for the discovery of new land. In other words, our logical capacities are limited to the "land of truth", defined by the functionality of the system of cognition of finite beings. Kant's advice for our understanding is therefore: Cobbler, stick to your trade and make the best of it.

3) Dialectics – From Kant to Hegel

3.1) On the Fundamental Difference Between Kant and Hegel

It will come as no surprise to you TRIZnics what would happen to reason if it ignored Kant's advice and transcended the natural limits of the understanding's functionality: That's it, it would run into contradictions with itself. That is basically what the *dialectical part of the CPR* is about. Kant shows that many of the problems in metaphysics are due to subtle abuses of our understanding. It is, however, worth pointing out that whether something is an abuse or not is determined with reference to the functionality of the system of cognition, which is outlined in the *analytic part of the CPR*. The functionality of the understanding is therefore understood as far as it belongs to the system of cognition.

According to Hegel, one of Kant's greatest merits was to have shown that the contradictions outlined in the *dialectical part of the CPR* – contradictions that mirror metaphysical disputes from the history of philosophy – are not just any old contradictions. On the contrary, they are contradictions that arise immanent to the functionality of the system of cognition that is the subject of the analytical part of the CPR. In other words, these contradictions – and, thus, the respective metaphysical conflicts – are, under certain conditions, necessarily generated by the design of the system of cognition of finite beings.

The fundamental difference between Kant and Hegel, however, can be seen in their way of dealing with these contradictions. While Hegel takes them as a sign of the inner, systemic contradictions of the system of cognition Kant advocates that we take caution to not overstep the line that leads us into contradiction. In other words, Hegel thinks like an inventor who looks for the original source of these contradictions in the analyzed system and who is ready to question the system itself. In contrast, Kant thinks like an optimizing engineer who opts for adjusting the demands rather than changing the system. In other words, he takes the functionality of the analyzed system for granted and looks how it can best function with regard to the system's purpose and the functionality of its respective sub-systems. Given his approach to these contradictions, the Hegelian critique of Kant's logic is threefold, an issue that I will take up in the next three sections.

3.2) Hegel's First Criticism Against Kant: On the Dependence of Kant's Logic on a Preconceived Concept of Cognition

First, Hegel criticizes Kant's method by saying that the transcendental approach forces Kant to choose objective representation as the paradigmatic type of cognition that is to be analyzed in the first part of the CPR. Despite the fact that our understanding gets wrapped up in contradictions with itself when it leaves the safe ground of possible experience, Hegel criticizes Kant for opting to limit the realm of truthful cognition and thus logic itself instead of abandoning the presupposed conception of cognition. In other words, in spite of the insights gained from the dialectical part of the CPR, Kant sticks to the system that was analyzed in the analytic part of the CPR. To take up Altshuller's famous example from Engel's *History of the Rifle* (Marx/Engels, 1972, vol. 15), one might say that Kant behaves like the engineer who chooses to stick to the state of the art of the muzzle-loading system and is thus forced to accept a compromise between pinpoint accuracy and loading speed.[3] The compromise of Kantian epistemology concerns our ability to experience objects in general. We cannot know the thing in itself, but can only acquire knowledge of appearances.

Against Kant, Hegel criticizes the dependency of cognition on sensibility that leads to this compromise. According to Hegel, the insufficiency of the logical forms analyzed in the analytic makes itself apparent in the dialectical part of the CPR, and this deficiency can be traced back to the dependency of cognition on sensibility in the Kantian system. Although it might seem that this criticism only bears on the whole of Kant's analytic, and not on the analysis of the understanding per se, Kant's analysis of the understanding is motivated by this systematic concern. Thus, Kant only analyzes the role the understanding plays in producing objective representations.[4] As a consequence, the logical forms unveiled by this analysis only work within this setting.

[3] Muzzle-loading rifles must be loaded from the front. The longer the barrel, the longer the loading process. Thus, in order to decrease the time needed for loading, the barrel must be shortened. However, the longer the barrel, the greater the accuracy. Hence, there is a contradiction between the two goals: increased accuracy and decreased loading time. By sticking to the muzzle-loading system, the best solution that can be found is a shaky compromise. This mutual dependency of parameters that prevents them from attaining a better state (the elimination of negative effects included) is a *technical contradiction* (Altshuller, 1973).

[4] See, for example, the following interpretations of Kant's CPR: „[...] the absolutely fundamental question of Kant's revolutionary new approach to philosophy as adumbrated in 1772 [...] is this: how are objective mental representations possible?" (Hanna, 2001, 2) or „Kant's most basic transcendental question does not, as his own characterization of his project suggests, concern the condition of the possibility of synthetic knowledge a priori, but the conditions of the intelligibility of representational objectivity" (Brandom, 2006, 51).

3.3) Hegel's Second Criticism Against Kant: On the Historical Dimension of Logic

Hegel's second criticism points in the same direction. It addresses the ahistorical approach Kant takes. Instead of understanding logic as something that changes and develops over the course of time, Kant conceives logical theory as having been complete since the time of Aristotle. However, Hegel would say that if Kant had understood logic as a system of epistemic practices that develops over time, he would have seen that the first analytic part of his CPR is nothing else than a profound analysis of the state of the art of logic in his own time. Moreover, he would have seen that the dialectic part of his CPR shows the deficiencies of the analyzed system and reveals its developmental potentials.

3.4) Hegel's Third Criticism Against Kant: On the Improvement of Cognition

In addition, Hegel could say, Kant would have seen that a third step was needed. This step would have consisted in the reformulation of the notion of cognition that could be taken as the paradigm on which logic would have to be founded. Given the analogy drawn between the CPR and Altshuller's example from the *History of the Rifle*, this step would correspond to the replacement of the muzzle-loading system by the breech loading system.

From a logical point of view, this is the origin of Hegel's famous three step model, which consists of an analytic part, a part in which a dialectical contradiction is unearthed, and a speculative part in which this contradiction is resolved. This third step can be viewed as something positive, because it is concerned with problem solving: it yields a result that can undergo further analysis and so on and so forth. Thus, dialectics not only produces negative results, as in Kant, but positive results. Moreover, each of these positive results contains something new, insofar as it allows us to go beyond the limits of the subject that had been analyzed before. In this sense, the third step is creative.

The three step model outlines the smallest unity within Hegel's model of the ideal developmental course of logic. Since the third step yields results that can in turn be made the subject of further analysis (i.e. of a further first step), Hegel describes the overall ideal developmental course of logic as a circle of circles. Note that from Hegel's perspective, logic is about the way thought explains itself. Since Hegel chooses a developmental perspective in order to show how thought can encounter this challenge, he starts with the very insufficient beginning of logical theory and goes step by step through ever more sophisticated versions of logic on to its perfection. This perfection consists in the development of the type of thought that, when explaining itself, no longer runs into contradictions that cannot be overcome by this thought itself.

Hegel calls this highest form of cognition *absolute knowledge*. Its notion is first elaborated in the course of the *Phenomenology of Spirit* and serves as the mode of cognition that underlies the entirety of Hegel's *Science of Logic*. This type of thought is able to take itself, its respective way of thinking, and the resulting contradictions as subject. On the basis of that it is able to develop itself further. The way in which it proceeds is retrospectively spelled out at the end of the *Science of Logic*. It is called the *absolute method*, which is better known under the name *dialectical method*.

Hegel's *Science of Logic* thus makes explicit how thought proceeds when developing an explicit account of itself, i.e. when doing logic. This self-reflective version of development is even more complex than simply developing something – for example a technical system – further. In the Hegelian *Science of Logic*, the latter is a logical part of the former. The development of technical systems, for instance, belongs to the chapter on teleology.

4) From Hegel's Absolute (Dialectical) Method to the tradition of TRIZ

Moreover, Hegel's absolute method not only stands at the very beginning of the development of TRIZ in a systematic sense. The latter also has its historical origins in Hegel's philosophy. When Altshuller introduced contradiction oriented speculative thinking into engineering, it already had undergone some significant changes. These changes were informed by Marx's reevaluation of philosophy's purpose. Famously, Marx thought philosophy should not just try to understand the world, but to change it.

In accordance with this shift in perspective, Hegelian dialectics had to be – as Marx claimed (Marx/Engels, 1962, vol. 23, 27) – turned on its feet. As a result of this, Hegelian dialectics became materialist, a transformation carried out by figures like Engels, Lenin or Stalin.

Altshuller took up the pragmatic kernel of one of these transformations and developed dialectical thinking further into a method for creatively solving technical problems. Although there are – as far as I know – no direct references to Hegel in Altshuller's work, it is not only the famous example from Engel's *History of the Rifle* that shows that Altshuller was aware of the tradition of thought to which his theory belongs. "The development of technical systems," he writes, "like all other systems is subject to the general laws of dialectics" (Altshuller, 1984, 32). This citation clearly points to one of the materialist transformations of dialectical thinking.[5]

In 1973 Altshuller's work first entered the GDR via translation (Altschuller, 1973; later also Altschuller/Seljuzki, 1983; Altschuller, 1984 and Altow 1986/1977). The theory helped give rise to the so-called inventor school movement (see for example Rindfleisch/Thiel, 1994, DABEI, 1993). It also underwent some transformations, the most significant of which was the so-called ProHEAL, the *Guidelines for Developing and Resolving Problems in Invention* by Hans-Jochen Rindfleisch and Rainer Thiel (1986; 1988; 1989).

As for the philosopher Rainer Thiel and the engineer Hans-Jochen Rindfleisch, they were aware of the dependency of Altshuller's TRIZ on Hegel's logical considerations. In the materials on the ProHEAL, Rindfleisch and Thiel (1988, 11) cite Hegel from Lenin's synopsis's of the *Science of Logic* (Lenin, 1964, vol. 38), writing that "method is the consciousness of the form of the inner self-movement of the content of logic" (Hegel, 2010, 33). The founder of the ProHEAL's descendant WOIS (*Contradiction Oriented Innovation Strategy*), Hansjürgen Linde, mentions the same citation when he later gave Hegel's formulation a "user-oriented" thrust, which reflects the above mentioned changes Hegel's thought had undergone in the meantime: "Method is the conscious search for the usability of the inner self-movement of the object that is to be influenced" (Linde/Hill, 1993, 5, my translation).

[5] It would be interesting to know which version of materialist dialectics informed Altshuller's approach; this might be a question for future research.

Indeed, this is an interesting transformation of Hegel's absolute method. Looking in some more detail at what this definition says, we come back to the starting point of our discussion, namely to Kant's *Critique of Pure Reason*. As I said in the beginning, Kant's analysis of the understanding was built upon a conception of cognition oriented towards the recognition of objects. In contrast, Hegel founded his logic on a self-reflexive form of cognition. This type of cognition is also concerned with the recognition of objects, but this is only a necessary aspect of its recognition of itself.

Although the Marxist, pragmatist shift from recognizing the world to influencing it clearly shines through in Linde's transformation of Hegel's conception of method, it remains, analogous to Kant's notion of cognition, the object that is to be influenced. This, however, cannot be the last word on things, at least not from the point of view of Hegel's logic. The reason for this is simple. Influencing objects, i.e. creating and developing artifacts further, cannot be an end in itself, since artifacts themselves are not ends in themselves, as Hegel argues in the *Science of Logic* (Hegel, 2010, 651-669). Rather, they are created or developed for particular purposes. In order to understand how these purposes develop, the realm of artifacts must be transcended.[6]

Although Linde's transformation of Hegel's notion of method moves from a Hegelian point of view back to a more Kantian paradigm, he took up the interdependency between the development of artifacts and the development of the purposes that determine their development as the subject of his method. Linde inherited this theoretical achievement from the ProHEAL method of Rindfleisch and Thiel.

Before I turn to the discussion of the crucial difference between Altshuller's *Algorithm of Inventive Problem Solving* (ARIZ) and Rindfleisch and Thiel's *Guidelines for Developing and Resolving Problems in Invention* (ProHEAL), I will first summarize what Altshuller himself thought about the development of his ARIZ. This discussion will allow me to set the development of ProHEAL and WOIS and

[6] According to Hegel's chapter on teleology in his *Science of Logic*, artifacts are in the need of someone who creates and preserves them. For this reason, it can be asked what their creation or conservation is for. If it turns out that the artifact in question is useful for the creation or perseverance of a further artifact the question can be repeated and so on and so forth. The regress can only be stopped if a more complex type of end is presupposed, which does not have these features that are typical for artifacts.

their relation to the development of Altshuller's TRIZ against the backdrop of Hegel's *Science of Logic* on which all these approaches draw.

5) Altshuller's Reflection on the Development of TRIZ

In *Creativity as an Exact Science* (1984/1979), Altshuller distinguishes three stages of the development of TRIZ and anticipates a fourth stage.

The first stage was marked by the discovery of what Altshuller called the *objective concept of invention*, which is based on the conception of so-called strong solutions. Strong solutions, as opposed to weak ones, involve the elimination of a technical contradiction contained in the problem the inventor was trying to resolve. Reserving the term *invention* only for such strong solutions, Altshuller defined an invention as the elimination of a technical contradiction (Altschuller, 1973, 85). In doing so, he began to implicitly base his theory on dialectical logic.

While the first stage of the development of TRIZ can thus be viewed as Altshuller's entry into dialectical thinking, insofar as he attributed a productive role to contradictions, the second stage makes a turn towards logic. According to Kant, logic is not about how the understanding thinks – this would be only of psychological interest –, but how it ought to think (Kant, 1923, 16). According to Altshuller, the second stage in the development of TRIZ marked a shift in its approach to understanding inventing, moving from a descriptive, psychological approach towards a normative approach. Instead of going on to study how great inventors actually proceeded, Altshuller began to think about how they should proceed in order to find strong solutions – i.e. to come up with good inventions. To this end, he built on his concept of invention, which allowed him to take a systematic perspective on the process of inventing. He analyzed thousands of patents of high quality inventions from different fields and reconstructed the respective ideal inventive process using his objective notion of invention. The overall goal was the strong solution; that is, the elimination of technical contradictions. Taking his notion of invention as a starting point, he began developing guidelines for detecting, analyzing, and overcoming technical contradictions. He called it the *Algorithm of Inventive Problem Solving* (ARIZ). Its purpose was not to replace the inventor's abilities or knowledge. Rather, it was conceived of as a guide for preventing inventors from making too many mistakes and for providing them with useful strategies for inventive problem solving (Altschuller, 1984, 30f.).[7] Again, this is what Kant says about logic. It cannot guarantee that we think truthfully, but it helps keep us from thinking irrationally. The same holds for Altshuller's ARIZ with respect to inventing successfully. The ARIZ can thus be viewed as a logic of invention, which is, because of its positive orientation towards contradictions, a dialectical logic of invention.

Note that there are some logics of invention that are not explicitly dialectical. A case in point is W. Brian Arthur's (2007) *A Structure of Invention*, according to which "invention has a logic – a systematic structure" (Arthur, 2007, 286). According to Arthur (2007, 278), a particular need stands at the beginning of every invention. Some practitioners might be aware of this need and the problem it poses, but none of them are able to find an adequate solution because current technology is unable to solve the problem. Inventors, or originators as Arthur prefers to call them, nonetheless accept the challenge. They "may encounter the situation as a need to be fulfilled or a limitation to be overcome; but they quickly reduce it to a set of desiderata – a problem to be solved" (Arthur, 2007, 279) with an invention. Let us call this scheme, according to which a situation S must be reduced to a problem P that can be solved with an invention I, the SPI-scheme.

The SPI-scheme is perfectly in keeping with Altshuller's conception of the overall structure of the process of invention. The respective situation S, in which needs or limitations are experienced, initially appears in the form of a poorly defined problem (Altschuller, 1984, 24). A solution must be found, but current technology is

[7] Up until 1985, Altshuller understood the ARIZ as a work in progress. Over the course of time new versions evolved. All of them have been tested out in seminars and in practice. Accordingly, the ARIZ has been constantly renewed, with the result that some tools which were the most important in the early phase of the theory's development were completely left aside in the later versions. For example, the latest versions of the ARIZ – which fall into the third stage of the theory's development – no longer contain the matrix of contradictions and the coordinated inventive principles, which were part of the most important tools in the early versions. The odd thing about this is that today TRIZ is often associated with the contradiction matrix and the inventive principles. Gadd (2011), for example, draws heavily on these tools and the contradiction matrix got frequently updated (for example Mann et al., 2003). This might partly be due to the fact that the reception of Altshuller's theory depends on the available translations. One of the four Altshuller books in English (Altshuller, 1998) is dedicated to the 40 inventive principles. Another one, *The Innovation Algorithm* (Altshuller, 2005), is dedicated to the ARIZ, but the original text is from 1973. Moreover, the exclusion of the contradiction matrix and the coordinated inventive principles from the ARIZ has sometimes silently been taken back. For example, in 1999 Orloff (2000) took up the ARIZ in its latest version, the ARIZ-85C, slightly modifying its vocabulary while making significant modifications to its conceptual content by reintroducing, in step 1.7, the contradiction matrix and the inventive principles; this modified version was called ARIZ-85/99. He did not point out the difference with Altshuller's original version, which at this time was only available in Russian (at least in Germany; the first non-modified German version of the ARIZ-85C can be found in Koltze/Souchkov, 2011). In contrast, a systematic criticism of the contradiction matrix and the inventive principles can be found, for instance, in Möhrle (2003) and Zobel/Hartmann (2009).

not adequate to the task. Therefore, the inventor is needed. Altshuller calls such tensions between intention and ability – we know what we want, but we do not know how to get there – *administrative contradictions*. When such contradictions emerge, one is in the midst of an *inventive situation*. Altshuller claims that the heuristic potential of such situations is zero. The proper problem solving process begins when an effort is made to transform the inventive situation into an appropriate inventive task. An ordinary task becomes an inventive task if and only if the elimination of a technical contradiction is a necessary condition for its resolution (Altschuller, 1973, 80). Therefore, it must first be determined whether the administrative contradiction can be transformed into an inventive task, which can then be solved by an invention at the end of the process.

Against the backdrop of the SPI-scheme, the crucial difference between Arthur's and Altshuller's approach concerns the passage from S to P. In contrast to Altshuller, Arthur neglects to analyze the necessary transformation of S into P. He only discusses the passage from P to I, which he views as a recursive process of problem solving. He places his focus on finding the base principle – "the idea of some effect (or combination of effects)" (Arthur, 2007). Accordingly, Arthur defines invention as "a process of linking some purpose or need with an effect that can be exploited to satisfy it" (Arthur, 2007, 275).

In contrast, Altshuller defines invention by referring to the type of problem that is to be solved. Accordingly, all ARIZ versions begin with the detection of technical contradictions, i.e. with the transformation of inventive situations into tasks for inventors, i.e. with the passage from S to P. Since Altshuller considers the problems P in the SPI scheme as contradictions, his theory is dialectical. Arthur's theory, in contrast, is undetermined with respect to this question and, as a consequence, less concrete. Because of the abstractness of his account of the nature of the problems to be solved, a doubt might be raised as to whether Arthur's logic of invention can be made into a method of invention like the ARIZ. Indeed, it would be interesting to know whether a logic of invention that can account for the whole SPI-scheme has to be dialectical if it is to be turned into a method of inventing. This, however, lies outside the scope of this paper.

What is more, Altshuller's work on the ARIZ led him to the third stage of the development of his theory. Basically, technical contradictions come about when a technical system gets stuck somewhere on its path towards its ideal form, i.e. towards becoming the ideal machine. This *Ideal Final Result* (IFR), as Altshuller called it later, is achieved when there is nothing more to complain about: The functions are perfectly fulfilled, the device costs nothing, no energy is wasted etc.

Over time, Altshuller increasingly became aware that the inventor's role is to develop technical systems during all stages of their respective evolutionary process by eliminating the contradictions that stand in the way of their further evolution. Seen from this wider perspective, a good invention should be a further step in the respective technical system's development towards its *Ideal Final Result* (*IFR*). With regard to the study of patents, the focus was shifted from the analysis of individual inventions to the analysis of the laws of the evolution of technical systems, as Altshuller puts it. At this stage of the theory's development, such laws were considered to be the very foundation of the science of invention.

In 1979, Altshuller himself identified this state of his theory's development. The organization of research and teaching had become much more professionalized. Institutes and inventor's schools were founded in the USSR. In 1978, there were about a hundred such schools throughout the Soviet Union. Developing and experimenting with the theory, improving the ARIZ, and educating inventors had become a collective enterprise. At this third stage, Altshuller was already anticipating a fourth. He thought that at this fourth stage the theory would help develop technical systems according to a plan, rather than having to wait for an invitation from the actual state of things. Altshuller seems to have been anticipating the emergence of a branch of TRIZ that was later called the *Theory of Engineering (Technical) Systems Evolution* (TESE) (see for example Souchkov, 2013). But in the meantime Altshuller's ideas had also arrived in the GDR, where the anticipated fourth stage was carried out in an entirely different way, namely in form of the *Guidelines for Developing and Resolving Problems in Invention* (ProHEAL).

In the following sections I will discuss this difference. Moreover, I will argue that the authors of the ProHEAL, Hans-Jochen Rindfleisch and Rainer Thiel, brought Altshuller's TRIZ closer to being a more complete theory of invention. I will show that this can be said from the point of view of both the SPI-scheme of invention and Hegel's *Science of Logic*. However, the door opened at this stage of the theories development makes everything much more complicated, since it becomes obvious that *invention* and *innovation* are eminently political terms.

6) On the Difference between ARIZ and ProHEAL – A Step Towards a More Complete Theory of Invention

The crucial difference between ProHEAL and ARIZ can be found in their respective starting points. According to the SPI-scheme of the process of invention outlined above, an inventor encounters a situation S that must be transformed into a well-defined problem P that is to be solved by an invention I. While Arthur's theory only explains how to go from P to I, the ARIZ begins with a situation S that is in some way given and that simply needs to be made into a task for inventors, i.e. transformed into a well-defined problem P.[8]

In contrast, the ProHEAL states that appropriate invention starts with an analysis of the needs. The ProHEAL therefore begins by a case specific analysis of the factors that give rise to the situation S in the first place. This step, which precedes the search for a formulation of the inventive task, goes hand in hand with the determination of the so-called Target Value towards which the development of a technical system is supposed to move in accordance with the social need. The role of the Target Value (TV) corresponds to the role of Altshuller's Ideal Final Result (IFR), insofar as it prescribes the development's direction. The TV, however, is more concrete than the IFR, which can be seen from how it is determined.

According to ProHEAL, the TV falls into four components: functionality (TV_1), economy (TV_2), controllability (TV_3), and utility (TV_4). While the components TV_1, TV_3 and TV_4 make up the *usefulness* of a technical system, *effectiveness* is defined as the optimal usefulness (i.e. the optimal combination of TV_1, TV_3 and TV_4) with minimal financial and material costs. The goal for a problem's solution is the *total ideal*. It consists in the optimal proportion between the so-called partial ideals of the components $TV_{1\text{-}4}$. These partial ideals are the *ideal of a heavenly useful effect* (TV_1), the *ideal of profit without any effort* (TV_2), the *ideal of self-controlling* (TV_3), and the *ideal of universality* (TV_4). According to Rindfleisch and Thiel (1988, 22), the optimal proportion of the partial ideals is at the same time the maximal possible effectiveness, the so-called *total ideal*, which is also called the

[8] In the first three stages of the development of TRIZ, this givenness consisted in the emergence of inventive situations. As for the fourth stage predicted by Altshuller – at least in the form of the Theory of Engineering (Technical) Systems Evolution – the development of the technical system can be planned by the inventor. That the development of technical systems can be planned follows from the laws of technical evolution, according to which the shape future inventive situations will take is predictable. Thus, the inventive situations – at least as far as they can be foreseen – are in a certain respect given by the very laws that the development of technical systems follows.

ideal of balance. It can be visualized as the barycenter of a tetrahedron whose corner points are the partial ideals TV_{1-4}.

This barycenter, i.e. the Target Value TV, is to be confronted with the actual effectiveness of the respective technical system in the current state of the art. This brings about the target vector for the necessary technological development. In order to get on the developmental path indicated by this vector, the *demands* (*A*nforderungen), *conditions* (*B*edingung), *expectations* (*E*rwartungen) and *restrictions* (*R*estriktionen), the so-called ABER[9] – are to be determined for every component of the TV in accordance with the social need. To this end, a so-called ABER-matrix of the following type is used:

ABER-Matrix

	TV1 Functionality	TV2 Economy	TV3 Controllability	TV4 Utility
A) Demands				
B) Conditions				
E) Expectations				
R) Restrictions				

While the category *demands* accounts for all the technical system's features of usage, the *conditions* category concerns the special social and technological conditions under which the system is used. The category *expectations* is about latent social needs that have not yet become clear, while the *restrictions* category concerns overall social need. This category is by nature limiting. These limits result from the scarcity of natural and societal resources on the one hand and from ethical and political norms on the other. To respect such restrictions, as Rindfleisch and Thiel write, is essential for progressive development. The more serious such a restriction is taken, the more likely it is to produce fruitful results.

The number and nature of the ABERs gathered together in the matrix with regard to the TV's components define the complexity of the TV. Moreover, the matrix makes it possible to distinguish their importance and nature. According to Rindfleisch

[9] ABER basically means "but".

and Thiel, the expectations are less important, while the demands and the restrictions are the most important. The ABER-matrix therefore foresees a systematic synthesis of the ABERs that make up the TV.

Note that the ultimate goal of inventive problem solving is the *total ideal*, which consists in the maximal possible effectiveness. Moreover, the TV is to be determined in accordance with this goal. Since it consists of the systematically ordered ABERs, the increase of the TV depends on these ABERs. In order to make this relation operational, these ABERs have to be turned into so-called *Technical-Economic Parameters* (TEP). The formulations of these TEPs have to be standardized in a way such that their increase reflects an increase of the overall effectiveness of the technical system. Moreover, particularly those TEPs are to be increased whose improvement promises the largest improvement of effectiveness from society's perspective. This imperative is reflected in the following formula ("^" means an increase): $E\^{} = f(TEP_1\^{}, TEP_2\^{}, TEP_3\^{}, ..., TEP_n\^{})$.

As long as a technical system has not yet reached its ideal form, so-called *Technical-Economic-Contradictions* (TECs) will arise – that is, if the imperative is taken seriously. These contradictions arise when the improvement of a certain TEP causes the deterioration of one or more other TEPs. The understanding of the roots of these TECs is a matter of analyzing a specific system. The ProHEAL guides the inventor through the different stages of this process in order to find the root of these contradictions. To this end, Rindfleisch and Thiel distinguish between different types of contradictions, but this lies outside the scope of this paper.

Without going into details, it is worth pointing out that the contradiction between different TEPs makes clear that these contradictory parameters are dependent on a parameter that is important for the technical functionality of the respective system. These parameters are so-called Technical-Technological Parameters (TTP). The distinction between TEPs and TTPs allows one to represent the totality of a system's TECs in the so-called *Matrix of Demands*. Within this matrix, the columns are reserved for TTPs and the rows for TEPs. The arrows indicate whether the value of a TTP has to be increased or decreased in order to yield an increase of the respective TEP. If one and the same TTP has to be increased and decreased at the same time, there is a TEC between the respective TEPs.

Matrix of Demands

TEP\TTP	TTP1	TTP2	TTP3	TTP4
TEP1	↑			↑
TEP2			↑	↓
TEP3	↓	↑		
TEP4		↓	↑	
...				

With regard to the fictional example of this table, there are TECs between TEP1 and TEP3, between TEP3 and TEP4 and between TEP1 and TEP2.

The distinction between TEPs and TTPs not only allows one to represent a system's TECs in the Matrix of Demands. If one can model TECs in this way, then one can also intentionally produce them. By implication, one can thus purposely bring forth inventive tasks, which, according to Altshuller, consist in the elimination of such contradictions. Like with Altshuller's anticipated fourth stage of the development of TRIZ, the inventor must not wait any longer for an inventive situation to come to him so that he can transform it into an inventive task. However, the reason for this is quite different with ProHEAL. Altshuller's TRIZ has a tendency towards technological determinism. Technological determinism means that one holds to the claim that with perfect knowledge of the laws of technological evolution, one can develop technical systems according to a plan even before inventive situations arise. In contrast, ProHEAL also deploys insights from the study of technological evolution. However, the reason why a user of ProHEAL does not have to wait for an inventive situation to arise is that ProHEAL begins with an analysis of social need. Based on the results of this analysis, TEPs can be articulated. In turn, inventive tasks can be intentionally produced before the unsatisfied need becomes urgent in an inventive situation.

7) Conclusion

To sum up, I have shown that Altshuller's method of inventive problem solving developed out of Hegel's dialectical logic. The latter's purpose can, in my opinion, be best explained if it is understood as a solution to the problems posed by Kant's classical approach to logic. Moreover, I have tried to show that Altshuller's own reflections on the development of his theory mirrors how it approximates gradually the essential features of Hegel's dialectical logic. Starting with an orientation towards contradictions, Altshuller then turned from a psychological approach to invention towards a logical approach. In doing so, he finally realized that his dialectical logic of invention was essentially a logic of technological development. However, instead of looking for the very sources of this development outside of the realm of technology, his theory remains within the boundaries of technology. From the point of view of Hegel's *Science of Logic*, the adequate developmental step would have consisted in transcending the domain of technology in order to determine the original sources of this development – the needs to be satisfied. Rindfleisch and Thiel's ProHEAL accomplished this important step forward in the history of the contradiction oriented theories of invention. In other words, it could be said that the ProHEAL took a step towards a more adequate theory of invention and as a result, it could be viewed as a further developmental step of Altshuller's TRIZ.

This can also be seen from the perspective of the SPI-scheme of invention. While Arthur's (2007) theory of invention can only account for the passage from the well-defined problem P to the invention I, Altshuller's ARIZ starts a step earlier with the passage from the inventive situation S to the well-defined problem P. The ProHEAL, however, starts a step earlier by analyzing the social need that stands at the root of the inventive situation S. From this perspective, the ProHEAL covers more essential elements of the process of invention, which in a sense makes it a more complete account of invention.

Starting with the situation itself, however, has a further methodological implication: ProHEAL not only explains how inventors should analyze a situation, but also contains an explanation of how inventive tasks can be intentionally produced. This means that invention can not only be planned (as in TRIZ), but also guided in a particular direction. The direction an invention takes depends on the way the need to be satisfied is formulated. Because of this shift in perspective, the theory of invention steps out of the domain of technology and becomes a part of politics and ethics: for example, the category of *restrictions*, which is crucial for determining the Target Value (see section 6) and thus the direction of technological development, expresses limitations that are set by political and ethical norms, which confirms Schmidt's (2007) claim that innovation should be characterized as an eminently political category.[10]

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[10] Aside from the internal logical reasons for beginning the analysis of the process of invention with the origins of the situation S, the difference between ARIZ and ProHEAL can probably be best understood when one considers the different contexts in which the theories were developed. TRIZ/ARIZ was developed as a tool for professional inventors in the USSR in order to solve problems on demand. In contrast, the GDR inventor school movement that shaped ProHEAL emerged out of the initiative of individuals working in state-owned industrial enterprises in the GDR (Rindfleisch/Thiel, 1994). These enterprises had to meet the demands set by a yearly economic plan. As is common knowledge, however, control economies lack the dynamic of market economies. In this context, the ProHEAL was designed as a means for turning ordinary engineers into inventors. Moreover, the authors of the ProHEAL wanted to empower people to autonomously determine what society needed and which problems needed to be overcome in order to ensure society's progress (private communication with Rainer Thiel).

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