A FORMAL THEORY OF TECHNOLOGY?

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1. INTRODUCTION

It is a very old and serious question in philosophy—not only within the Western context—how knowledge and practice are interrelated. So the basic question of any philosophy of technology is how to analyze the relation between science, technology itself, and practice. Since the beginnings of culture, mankind has acquired knowledge about nature, and our ancestors have talked about knowledge in the form of myths, theogonies, and cosmogonies, as well as stories and ballads, and much later in the form of written manuscripts and philosophical dialogues. In modern times we hand on our knowledge about nature in the form of protocols, based on experiments, observations, and theories. Moreover we use mathematical formalisms as a tool to describe our forecasts and explanations more precisely.

But this is not all the knowledge we have available about the world. Beside our social and organizational knowledge, we experience and collect knowledge about how to use things that are at hand, how to produce useful things, how to design artifacts in order to fulfill desired functions and to have means available for different purposes. We call this technological knowledge.

There is another, somewhat confusing discussion, about whether everything that we call knowledge about nature really refers to nature in a strong sense (using a material concept of nature). Some say that this alleged knowledge is not related to reality, but only to talk about reality (with all the contextual, cultural, social, and other "nonscientific" dependencies that implies). I might but I will not here mention Alan Sokal's hoax in *Social Text* (Summer, 1996). In any case, the question about different styles of realism in natural science seems to me an artificial one.

Another confusion has arisen, about the question whether our technological knowledge is genuine knowledge. Some say it is, and that it even determines the way we formulate knowledge in natural science; while others say that technology, because it is applied science, is merely a kind of degenerate natural science, a lower level of knowledge and no more. (This seems to be what most natural scientists think.)

Leaving these issues aside, I want to use Mario Bunge's (1967b, pp. 121 ff., 1972, 1979, 1983) analysis of the relation between natural science and technology, expressed in logical terms, in order to describe the inner structure of the relevant knowledge and practice. However, I want to push Bunge's analysis a little further, in order to show that the internal structure of technological knowledge does indeed have a structure different from the knowledge of natural science. (Nonetheless, I acknowledge that in practice, when the two forms of knowledge coincide—in setting up experiments or arranging processes under the influence of a goal—Bunge's conjecture about the nonderivability of pragmatic statements from deductive-nomological explanations, and vice versa, retains its validity.)

As I now investigate the theoretical kernel of technology more closely, from a point of view triggered by philosophy of science, I want to show that the kernel is not systems theory, as espoused by Ropohl (1979, 1998), but rather *action theory* of a very particular kind. (I do admit, however, that systems theory is useful, as a very rich phenomenological theory in the sense of Lakatos, 1974.) In order to make my point, I show that the so-called pragmatic syllogism is a consequence of Bunge's pragmatic statement, analyzed formally. I further argue that it is a syllogism *sui generis* and that it is derivable neither from a deductive-nomological explanation nor from a deontic modal calculus.

Some ontological and ethical consequences of these findings are discussed in the last section.

2. THE BASIC QUESTION

"Formalism is a good servant but a bad teacher" (Heege, 1984).

The relations between knowledge about nature and technological knowledge (or knowledge about our technical abilities) can be investigated by comparing the logical and semantic structures of the two kinds of knowledge in formal terms. But a formalism does not tell us anything about nature and technology in themselves. Galileo’s dictum—that the book of nature is written in the language of mathematics and the letters of this language are triangles, circles, and other geometric figures— is nowadays interpreted only as an educational hint and not as Platonic ontology. The fact that mathematics and formal means are usefully applied in describing nature (and technology as well) has provoked different answers that do not coincide with the ideas of Plato or even with Kepler’s reflections about basic regular geometric bodies. Modern answers, as given by Einstein (1921), or—completely different in his approach—by Hedrich (1993), are far from Platonism; but they do agree at least on the point that a formalism does not tell us anything about the object itself (*Ding an sich*).

Contemporary reflections are tending to a more pragmatic interpretation of what nature is. We conceive systems as descriptions of sections of reality, whereas the reality itself may be conceptualized either as hypothetical or as natural. The objective existence of a real world is believed to be true, but this is not provable by scientific means. This proposition rather represents a condition for the possibility of thinking about nature. We construct our world with the help of sensory data, and we assume that this mental design could be improved in a direction where we believe reality may lie. Systems theory uses formal methods and concepts in order to describe what we can design on a descriptive level. Therefore it makes no sense to speak about systems as existing in the ontological or ontic sense of *existere*. Of course, descriptions exist; we can share them within a community, and we can present them to everybody. But these descriptions have no ontological status like an *objet trouvé* or an artifact.

If a system is a description of a section of reality or of a process we would like to control, observe, or manipulate, then the system is something that has been produced, not discovered. A system is never discovered, but it can be invented or designed. Thus each system has an author and this author is pursuing such goals as describing, observing, controlling, changing, or mastering just the section of reality he or she has in mind. Since formal knowledge is not a substitute for knowledge about the world, the formal approach can only be a servant of these goals. Formalization means classifying elements of descriptions (mostly basic expressions within the description) in categories of a selected formal system, like logic, grammar, or mathematics. The power of formal description is the potentiality of deducing further formal statements as a set of consequences of a formal description. The interpretation of this formal set of consequence statements as statements about the world is only possible if the initial statements have already been interpreted in the same semantic or pragmatic closure. In other words, we can only deal with systems if the formal apparatus is embedded in the same context of meaning and action.

The basic question now is to analyze the conditions for the possibility of performing goal-oriented processes within reality, i.e., how to act within nature (reality) by means of artifacts or objects that can be used for achieving goals—i.e., how to act technologically. Ropohl (1979, 1998) has suggested that we conceptualize the instruments (means), the goals, the affected environments (the objects, processes, etc., that are the subject of our goals), and the processes of producing and using goals as systems in a wider context. This concept allows a first answer to the basic question of the philosophy of technology: according to Ropohl, the relation between knowledge (including goals, operative rules, etc.) and practice can be formulated as a relation between systems. The conceptual arsenal of systems theory—as long as it is used in a precise way, as Wiener (1968), Bertalanffy (1973), Klir (1985), Ropohl (1979), and others have done—allows us to understand a wide class of phenomena in technology, and technology's interaction with its organizational and social closure. But if the basic terms of systems theory are abused, turning them into metaphors or paraphrases of highly speculative theoretical sociology (as Luhmann, 1984, does), the ensuing confusion causes a rejecting attitude toward serious systems theory approaches by engineers or technicians. This has been criticized profoundly in other places.

But the basic question is not yet answered completely by systems theory. The notion of complexity has helped us understand the unusual behavior of certain processes that are very sensitive to variations of their initial and boundary conditions. This has provided an idea of how sensitive some processes may be—processes in which we have been convinced that we would be able to control them by simply preparing the relevant initial and boundary conditions. But the concept of complexity does not tell us anything about the conditions of the possibility of instrumental mediated impacts; it gives us only some terms of limitations. Complexity tells us what we cannot do instead of what we can do. The notion of emergence has been shown to be confusing; an extension of a system border, further embedding it in supersystems and their variables, may lead to an explanation of the originally unexplainable (see Roth and Schwegler, 1981).

The goal system in Ropohl's approach is a good descriptive means, but it does not tell us anything about the generation of goals and purposes within the organizational and societal closure of a technological context. For instance, it does not tell us that over-engineering may lead to new wishes, desires, and needs, and—as a result—to a complete new design.

The instrumental system in Ropohl's approach is a good means to describe machines and even a wide class of conjectured or theoretical devices that are state-space conceptualized; but there is no link between what a human being is able to do in, with, and by nature—i.e., what is possible—and what is not possible in reality. A systems theory that can predict an ultimate machine, a machine with all possible intelligible functions (of the sort fictionalized by Dürrenmatt or Lem) cannot be written, since systems theory is descriptive, not explanatory. Keeping this in mind, Ropohl's approach is useful, but it is no substitute for a theoretical kernel of technology.

3. SCIENCE, TECHNOLOGY, PRACTICE

The relation between pure science, technology, and practice is also strongly dependent upon the interpretation of technology itself. This interpretation is mostly the result of a selection process. The relevant terms are selected within a conceptual frame that itself covers a certain interpretation of nature as nature. For a philosopher this fact is not very astonishing since we cannot fail to select such conceptual frames in order to arrange our conceptual means. (See Langenegger, 1990, for a good summary of interpretations of technology by Ellul, Heidegger, Moscovic, and Ropohl.)

I will mention four approaches in philosophy of technology. The approaches all claim to "explain" technology, i.e., to understand why and how we are able to build and use artifacts.

1. Metaphorical Approach: Technology as . . .

This approach can be characterized by the use of metaphors when explaining technology. Technology as a projection of the functionality of our human body and organs (in a very broad sense; see Kapp, 1877) is a hypothesis that is closely connected with the exteriorization of human ability into the real world. When doing so, the exteriorized function is supposed to be extended, fortified, multiplied, and optimized (Rapp, 1974, 1978). All this is done by using instruments: technology as an instrumental, mediated handling of the world becomes able to compensate for the deficient modes of human being (Gehlen, 1957). Technology as a residual continuation of the act of creation has been proposed by Dessauer (1956) and others, and in this view technology is sometimes conceptualized as coextensive with human will or as an anthropological constant (as a *humanum*).

1. Effect-Oriented Approach: Technology has . . .

Technology has consequences and effects that can be more or less adequately assessed, and all these effects can be classified as intended or unintended, foreseeable or not, etc. The effect-oriented approach is sometimes very far reaching; for instance, some claim that technology has the potentiality to change human nature with genetic or even mass communication technology (Friedrich, 1997). If it is assumed that technology is able to change the natural, organizational, social, political, or communicational behavior of being human (i.e., the *conditio humana*), then technology is taken very seriously, but there is no explanation of technology. It is described and "explained" by its effects and by the properties it produces in an already technical world.

3. Normative Approach: Technology has to . . .

It is easy to list some requirements: that technology has to be designed according to our human and social needs; that technology has to support the conditions for responsible action; that technology has to serve welfare, economic growth, and prosperity; or that technology has to reflect true needs and genuine desires. At least this approach tries to fit technology in a normative way to human will. If one reflects that technology is normative anyway, since technological statements have a normative kernel (under certain conditions), then technological knowledge cannot be purely descriptive. We will come back to this position.

4. Naturalistic Approach: Technology is . . .

Technology "is a concrete being coming from the realm of ideas" (Dessauer, 1977). This idealistic view of technology tries to answer an ontological question considering the ontological status of artifacts. If one regards technology only as a kind of degenerate natural science, then it is the mere application of natural science knowledge. Within this context of definitions, Krämer (1982) has proposed that technology is the transformation of cause-effect relations into goal-means relations. Further, it has been suggested that technology is a mediation between the interests of technology's producers and consumers by means of an instrumental system (Rophol, 1979, 1998).

These four main approaches have different consequences for defining the relation between science, applied science, technological or engineering science versus engineering itself, and—therefore—the relation between science, technology, and practice.

Roughly speaking, one can classify the metaphoric, the effect-oriented, and the normative approach as having a weaker link with natural science knowledge than does the naturalistic approach.

The relation between scientific, technological, and practical knowledge has been characterized by Bunge (1967b) in terms of the relation between truth, effectiveness, and efficiency. If practice has no validating power, i.e., if the frequent successful application of technological knowledge, its effectiveness, does not ground the truth of the relevant scientific knowledge, then technology and science are at least independent with respect to their epistemology. In everyday engineering thinking, success does justify technological knowledge; questions of foundations of knowledge are less interesting in the context of research and development departments. Nevertheless, Bunge denies a logical connection (i.e., a formalizable relation that would guarantee a conclusion or a derivation) between scientific and technological knowledge.

A naturalistic view of technology (as proposed by Zoglauer, 1996), assumes that the theoretical kernel of technology is represented by lawful statements of natural science, whereas the normative view tends more to the assumption that the theoretical kernel cannot be merely descriptive (which is all that systems theories deliver), and must contain statements about goals, values, purposes, will, and desires. Metaphorical and effect-oriented approaches are descriptive, but they assume the possibility of epistemological or at least partially-historically-independent developments.

Here, the theoretical kernel will be considered to be systems theory of a particular kind: a theory of socio-technological interaction, or a social theory proper.

4. WHAT IS THE THEORETICAL KERNEL OF TECHNOLOGY?

Within the context of philosophy of science, one can distinguish a kernel of a theory (in physics, for instance, the mathematical theory of Hilbert spaces and the actual physical theory itself, the quantum mechanics) from the periphery; the latter consists of phenomenological theories (like scattering theory), models (like Bohr's famous model of a hydrogen atom) and "systems" like experimental set-ups, measurement devices, etc. (see Lakatos, 1974, and Kuhn, 1970).

It is well known that the phenomenological theories cannot be derived directly from the theoretical kernel, but it is possible to extend the phenomenological theories without modifying the theoretical kernel itself. Within an operative theory of a given technology (for instance, how to design a layout for a machinery park), systems theory plays the role of a phenomenological theory (a simulation, or an explanation of simulated behavior depending upon the selected structure). If systems-theoretical knowledge is interpreted as a description of a section of reality, natural science plays the role of a phenomenological or peripheral theory (for instance, finding an adequate working material with desired properties). The reason is that, within a substantial theory of a given technology, the pragmatic level of doing things cannot be described only by lawful statements; boundary conditions are a further necessary condition. Therefore natural science is not the kernel of technological knowledge; it is the knowledge of how to do things. This knowledge is transferrable without the knowledge of natural science, and the relevant technology can work with only preparatory knowledge (*know how* without *know why*; see Kornwachs, 1995a, 1995b, and 1996).

To continue this analysis, the actual kernel of technology must include goals, purposes, and desires; i.e., it must contain normative expressions. One could express this metaphorically: technology has to do with questions of human power and its human institutions. If this conjecture is true, technology has to be regarded as something that has to do with free will on the one side and natural law on the other side.

This may sound trivial. But it is an essential of philosophy of science to know whether the difference between natural science and technology is based only on sociological issues, or on methodological and formal issues of the inner structure of technological and scientific knowledge.

In natural science, a law holds even when one is not able to manage the antecedent condition. (For instance, we are not able to make experiments with black holes, but we believe in the correctness of the respective and relevant physical laws.) So the expression $A \rightarrow B$ represents a law independent of the paradox of implication. It is questionable whether the same holds for a technological expression.

Starting with a pre-selection of a philosophical interpretation of technology, technology is conceived here as work (labor) not against but within nature, using its behavioral regularities that can be expressed by the very formal notion of natural laws. Technology transforms causal relations into goal-means relations by applying goals to a knowledge about regularities in nature and society (in organizational systems). Whereas the results of technological developments can be interpreted as the exteriorization of human functions, or as projections of our organs into nature, or as a mixture consisting of prostheses, machinery, and games (Erlach, 1998), the actual structure of the technological act itself can be described formally according to the pragmatic statement of Bunge. However, it is obvious that the naturalistic view is not commensurable with Bunge's analysis. I will try to show that the pragmatic syllogism has a normative structure, and that we are not able to "control" nature in a direct way.

5. THE PRAGMATIC SYLLOGISM IS A SYLLOGISM *SUI GENERIS*

Bunge's pragmatic statement runs as follows: Let $A \rightarrow B$ be a deductive-nomological explanation, like $[\forall x\, (P(x) \rightarrow Q(x)) \wedge \exists a\, P(a)] \Rightarrow (Q(a))$. Let *B per A* be a rule, such that: If $A \rightarrow B$ is true, and *A is* an action (operation, effort, etc.) and *B* a wanted result ($\neg B$), and if *A* can be done or can be prevented, then try *B per A* or $\neg B$ *per* $\neg A$.

There is a difference between the statements A and B and the corresponding action *A* or real state *B* put into practice by *A*. We will come back to this distinction.

It is known that the true values of an implication are (1,0,1,1). Bunge states that a rule is not the subject of truth, but of effectiveness. The effective values of rule *a* are, according to Bunge, (eff, non eff, ?, ?). The signs of interrogation are due to the fact that if one is not able or ready to put the condition *A* into practice it is not possible to test the effectiveness of the rule. Whether this structure is coextensive with the paradox of implication, *ex falso quodlibet sequitur*, has been the subject of controversy (Zoglauer, 1996). If one does not agree, then the effectiveness of a rule is not derivable from the true values of the relevant implication and vice versa. This finding of Bunge (1967) still permanently provokes irritation when discussing this matter with technicians and engineers, because one of the consequences is that knowledge, structured in the form of a deductive-nomological explanation, cannot be used to ground a technological rule in a deductive way. The only way to do it is to state a pragmatic rule. Very often our knowledge is restricted to a technological rule, and we are not able to know all the natural science details; but despite this we are able to handle the problem technologically (rule-based action) with good results.

We can now analyze the status of law, rule, and action. $A \rightarrow B$ is a descriptive statement, expressing for instance a law. The pragmatic interpretation of $A \rightarrow B$, according to Bunge, can be written as

Prag. Int. $(A \rightarrow B)$ = *A produces B*.

This is still a descriptive statement. The rule

If *B* is wanted and *A produces B*
then try *B per A* or $\neg$*B per* $\neg$*A*

is a normative sentence, since it contains expressions including goals or obligations, like "it is a must," "it is forbidden." One can use the pragmatic interpretation of a lawlike expression in the sense that the term "produces" or expresses a meaning—like "it is causing," "it is operating on," "it is changing," "there is an impact such that *B*"—in order to formulate a pragmatic statement.

Such a rule for action we will call a "pragmatic syllogism."

In the following, we will discuss a pragmatic syllogism that is slightly different from the so-called practical syllogism of Wright (1991, pp. 933 ff.). The first is a result of the pragmatic interpretation of Bunge's technological rule (Bunge, 1967b, chap. 11); the second is an expression of deontic logic. The usual form of the practical syllogism is: If B is a goal, and only if A is done can B be reached, then A must be done. This can be written as

$$(O(B) \wedge (A \rightarrow B))) \rightarrow O(A).$$

If a pragmatic syllogism is applied, one can state that a subject who is doing technology or acting technologically has desires, wills, and wishes; and that he or she is a person or subject who is pursuing goals.

In the following, it is shown that the pragmatic syllogism is a syllogism *sui generis*. We can formalize it in the following way: There may be a certain lawful regularity that can be expressed by an implication ($A \rightarrow B$). For the modality of the state that is expressed by B, of "being wished" (as a goal or a must), an operator like $O_1(B)$ must be introduced. The resulting requirement—that the state described by A must be put in practice in order to have an effect, i.e., the mandatory modality—may be expressed by another operator like $O_2(A)$. Then the pragmatic syllogism can be written as

$$[(A \rightarrow B) \wedge O_1(B)] \Rightarrow O_2(A)$$

It has to be noted that the difference between a predicate expression, abbreviated by a propositional variable A, and an expression A that expresses a naturalistic interpretation of A as a real existing state in the world (or a process or action, not a description) refers to different types of expressions within the pragmatic syllogism.

The operators $O_1(B)$ and $O_2(A)$ can be interpreted in different ways:

$O_1(B)$: The state B, described by the statement that B, is an element of a goal system (i.e., $B \in \{Z\}$). This interpretation remains at a *descriptive* level.

$O_1(B)$: The state *B*, described by the statement that B, has to be put into practice (should be established). This is a *normative* expression, including obligation, interpretable as a technical ought or a moral ought (i.e., $< B >!$).

$O_2(A)$: The state *A*, described by the statement that A, is an element of a goal system (i.e., $A \in \{Z'\}$). This interpretation remains at a *descriptive* level.

$O_2(A)$: The action *A* that is putting things into practice such that it can be described by the statement A that has to be done under condition $O_1(B)$. $O_2(A)$ has to be done under condition of the obligation $O_1(B)$ as a technical or a moral *ought*.

A moral ought presupposes the possibility of choice. Considering the operator O as a technical ought, the practical syllogism has been interpreted to be purely descriptive (see Zoglauer, 1997, p. 38, and Wright, 1994, pp. 36-39.) It will be shown that this interpretation is not adequate.

The different possible interpretations lead to certain combinations within the pragmatic syllogism. Table 1 shows that there are only a few possibilities of interpretations.

		possible interpretations of O_1	
		descriptive $B \in \{Z\}$	normative $< B >!$
possible interpret-ations of 0_2(A)	descriptive $A \in \{Z'\}$	case (1)	naturalistic fallacy
	normative under condition $O_2(A)$ // $O_1(B)$	naturalistic fallacy	to be investigated further case (4)

	technical ought	naturalistic fallacy	case (2) $O_1 \neq O_2$
	moral	naturalistic fallacy	case (3) $O_1 = O_2$

Table 1: Possible interpretations of obligation operators

The expression "naturalistic fallacy" refers to the standard topic in analytical philosophy: there is no way to conclude from a pure descriptive statement (i.e., a statement that contains only descriptive terms) to a normative statement (i.e., a statement that contains at least one normative expression), and vice versa. Therefore, all those cases that lead to a naturalistic fallacy cannot be taken as serious candidates for an adequate interpretation. So we have to discuss the remaining cases (1), (2), (3) and (4).

In case (1) the pragmatic syllogism is a pure descriptive statement:

The expression	$(A \rightarrow B)$	$\wedge\ O_1(B)$	$\Rightarrow O_2(A)$
contains a	nomological expression	predication like $B \in \{Z\}$	predication like $A \in \{Z'\}$

Since B is at least a predicate expression like B = predicate P (of an individual constant a), written as $P(a)$, (where a is an individual constant, not a variable) the predication $O_1(B)$ is at least a statement with a predicate of second order $O_1(B) = O_1(P(a))$.

Here we are faced with problems in calculi dealing with predicates of higher order; i.e., incompleteness and undecidability problems. In order to avoid these troubles, we should omit the interpretation of the pragmatic syllogism as a pure descriptive statement. From a philosophical point of view it is a quite naive interpretation anyway, because a technical ought cannot be simply reduced to a descriptive statement. On the other hand a technical ought is not identical with a moral ought, since a moral obligation implies that Obligation $\rightarrow$ Permission, whereas the technological ought does not imply automatically a technological permission (in terms of technological possibility). For instance, in order to "repair" the sun and to prevent it to burn out, one should perform some "star technology" (according to Stanislav Lem); but nobody is able to apply such a technology practically. Thus, O (technologically) does not imply P (technologically).

In case (2) we concede that the statement is a normative one under the condition that both operators are not equivalent ($O_1 \neq O_2$). In a deontic interpretation, it can be shown that the expression

$[(A \rightarrow B) \wedge O_1(B)] \Rightarrow O_2(A)$ is falsifiable at least for the cases:

Truth value $([(A \rightarrow B) \wedge O_1(B)] \Rightarrow O_2(A)) =$ false for $O_1 \neq O_2$

Thus, for ($O_1 \neq O_2$) the pragmatic syllogism is not a true statement (theorem) within a deontic logic, if no further relation between O_1 and O_2 can be found. These possible relations should be investigated more in detail. (We omit that problem here.)

In case (3) we interpret the statement

$$[(A \rightarrow B) \wedge O_1(B)] \Rightarrow O_2(A) \;=\; [(A \rightarrow B) \wedge O(B)] \Rightarrow O(A)$$

as a statement of deontic logic with one common obligation operator O. But in this form the expression is not derivable in the standard deontic logical system Δ (see Kutschera, 1973, and Zoglauer, 1997). If one presupposes (pragmatically) that the substitution of O(A) = O(*A*) and O(B) = O(*B*) is possible, then only the following forms are derivable:

$[(A \rightarrow \neg B) \wedge O(B)] \Rightarrow O(\neg A)$
If *B* is wanted and *A* is a precondition for non *B*, you must not do *A*.

$[(\neg A \rightarrow \neg B) \wedge O(B)] \Rightarrow O(A)$
If *B* is wanted and non *A* is a precondition for non *B*, you must do *A*.

$[(A \rightarrow B) \wedge O(\neg B)] \Rightarrow O(\neg A)$
If *B* should be prevented and A is a precondition for B, prevent *A*.

Under the precondition that the application of Bunge's pragmatic statement could be expressible as a theorem of a deontic logic—i.e., that the knowledge foundation of technological handling can be performed in a rational way—the pragmatic syllogism is expressible logically only in a negative form, as

> desired state, precondition for prevention, do not put into practice the antecedent condition, or
> desired state, negative condition for prevention, so do put into practice the antecedent condition, or
> not desired state, precondition for fulfilling, do not put into practice antecedent condition.

The positive and the negative formulation of

> If *B* is wanted and *A produces B,* then try *B per A*

and

> If *B* is not wanted and *A produces B*, then try non *B per non A*

are therefore not equivalent. It seems that only the negative version holds.

6. CONSEQUENCES

The formal investigation of the pragmatic syllogism as a basic statement of applying causal knowledge (expressible in the form of a pragmatic interpretation of deductive-nomological explanations) leads to the astonishing result that only negative versions of the pragmatic syllogism can be true propositions in a logic that also contains normative or nondescriptive statements.

Either one is forced to accept naturalistic fallacies, which should be excluded here, or one is forced to come to the following hypothesis about the nature of technological action:

Hypothesis I: We cannot do things (like using or influencing artifacts and things at hand) in a direct way, but only by preventing undesired states.

Hypothesis II: If nature is describable by expressions like $A \rightarrow B$, we cannot use this knowledge directly but only by means of a preventing process. This is the essential characteristic of control, i.e., to prevent more or less completely what is not wanted.

This may give some hints of the status of technologically-induced processes. "Technology is not making nature a slave, but applying power within the realm of nature" (von Weizsäcker, 1971, 1977).

Thus we could argue that technology is the use of systems (real systems as sections of reality, described as systems, artifacts, knowledge systems) in preventing properties, states, or processes that we do not want. Since the set of goals we do not want is much more extensive than the set of goals we definitely want, all our technological action is necessarily incomplete and risks running into a corner where we do not want to be.

Here we have at least two further consequences. From an ethical point of view, responsibility within a technological framework means that we have to do everything that we can to prevent states and processes that are not responsible. Since our technological action is always necessarily imperfect due to the asymmetry between states we want and ones we do not want, we have to manage that most of those states, processes, and properties that are possible due to a certain technology are commensurable with agreed values and responsible goals. In other words, we can only try to maintain the conditions for responsible actions of all potentially involved persons and (maybe) institutions. This principle of maintaining conditions for responsible actions is presumably more general than other imperatives.

A second consequence is an ontological one. Let us summarize first some presuppositions: (1) Technology is the possibility of processes that are realizable in a natural world under the regime of purposes, aims, and goals. (2) We are only able to control our world by prevention and negation, not by putting wanted states directly into practice. If these presuppositions hold, a real state (facts) in the world we can observe has another ontological status, as a prevented state. Artifacts are then machines, the moving forms of which are not dependent upon their geometrical form (Kant, 1785); however, the geometric form (as a fact in a real world with existing artifacts) helps us to prevent movements we do not want. Thus a machine (or any thing at hand as an artifact, or before hand as an *objet trouvé*) can be considered as a filter or selector of natural processes and not as a generator of artificial processes. Therefore, technology is not an extension but a limitation of nature.

This consequence does not justify any kind of emotional technological pessimism, but it could be adapted to provide a deeper understanding of our technological way of using knowledge in dealing with the world.

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