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Review

The scope of problems associated with scientific and technological advance is extremely wide. Methodological analysis of the development of engineering sciences, along with a sociohumanistic review of innovations under elaboration, undoubtedly constitutes the necessary base for an effective strategy of controlling technological advance, which is turning into a paramount task under the growth of diverse risks. However, the philosophy of technology, which is a young discipline, and methodological studies as its most complex and labor-consuming part were duly recognized only in the past few decades. The problems faced by the philosophy of technology are covered in the article published below.

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Engineering Sciences: History and Theory

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Traditionally, not only commonplace consciousness but also the classical philosophy of science viewed engineering disciplines as part of the applied area. Arguments in favor of this point of view were based on an appeal to American experience and the history of the development of sciences in the United States. However, neither of them genuinely confirms this allegedly obvious fact. On the contrary, American experience has shown that, without new theoretical studies that accompany the use of "ready" scientific knowledge, even the smallest amount of progress in the practical sphere is impossible.

As a rule, the adherents of the above point of view on engineering sciences give the example of T. Edison—a "heaven-born" inventor, alien to pure science, who made true the American dream upon rising from an ordinary telegraphist to an internationally acclaimed inventor. However, Edison, who would often play to the public and act as a hick, created the first scientific–technological laboratory. Apart from him as a generator of ideas and a manager, the personnel of that laboratory included not only practitioners but also theoreticians (for example, specialists in mathematics, physics, fine mechanics, electrical engineering, and so on), who would develop his ideas to implementation [1]. Edison's activity is only one of the numerous facts from the history of science and technology that refute the trivial truth that natural science and mathematics generate new knowledge while engineering sciences merely apply it to engineering practice.

Recently, another noteworthy idea has become popular, which relates to the interpretation of the essence and role of engineering knowledge, namely, the idea of "postscientific rationality," allegedly emerging when not only specialists and scientists but also the entire society, especially customers, become involved in the generation of new knowledge. This means that bureaucracy, as it creates new regulations, reporting forms, and standards and, thus designing reality, becomes a legitimate producer of new knowledge. Something like that was already observable in Russian history when J. Stalin was proclaimed "a great engineer of socialist construction" and an equally great "engineer of human souls." The result of this socialist construction is universally well known: the Gulag and *sharashka*s, which enslaved workers, engineers, and scientists [2, p. 142]:

> Integrals and a club, philosophy and a hammer, a scientific laboratory and a factory, a scientific paper and a rifle, technology and Marxism—all these are the links of the extensive offensive against the remains of capitalism in our country and the weapons of our tornado-like onslaught on age-old backwardness.

The only difference is that now we are struggling against the remains of socialism to strengthen capitalism and create an information society.

We could give a large number of common misconceptions about engineering sciences. All of them are associated with historical myths, rooted in public and sometimes professional consciousness, and with an unwillingness to study the real history of science. This is partly the fault of representatives of engineering disciplines, who refuted their own history and refused to consider their branch of knowledge as a source of the advance of modern science. Although outdated books and textbooks have been "expelled" from libraries for technology, new works often reproduce the theses proposed in the old editions. Over the past few decades, the situation has begun to change owing to the fact that at least the philosophy of science has begun to get rid of false stereotypes and has turned to the study of the

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history of engineering sciences and to the development of the philosophy of engineering.

THE HISTORY OF ENGINEERING SCIENCES AND ITS METHODOLOGICAL ANALYSIS

The first classical engineering sciences emerged when technology could no longer develop without the regular use and generation of specialized scientific knowledge, primarily in mathematics and natural science. This genuinely revolutionary change was associated with the development of a new type of higher scientific–engineering education, i.e., higher engineering schools. For successful engineering activity, handicraft-type on-the-job training has become insufficient, which is confirmed, for example, by the fact that England, which had long been a leader in technological advance, lost its leading positions in the late 19th and early 20th century to Germany, where such education had become systematic.

In the course of the Industrial Revolution, several new social institutions emerged, aimed primarily at the development of technologically oriented science. In England, these institutions were private, while in centralized France, owing to the government efforts in establishing engineering schools, many such organizations appeared. The most important of them was the *École Polytechnique* in Paris, which became a model for analogous educational and, at the same time, research establishments in Europe and America, oriented toward the development of sciences with a view to meet practical engineering needs.[1] That was a kind of mutation in culture, because during the French Revolution many universities had been closed, and the citizens were expected to receive more practice-oriented education.

While France focused on the theoretical preparation of engineers, engineering science being understood rather as a mere application of science to engineering practice, the German higher engineering schools developed the idea of autonomous engineering science as a harmonious combination of scientific theory and engineering practice. The term *engineering science* was first introduced in daily use by the French engineer B. de Bélidor, who published the book *The Science of Engineers* at the Artillery School in 1729 [3].

The development of engineering sciences was associated with shaping engineering knowledge along the lines of other disciplines, primarily mathematical and natural sciences. As a result, professional communities were formed, similar to the scientific communities of that time; scientific–technical journals were established; research laboratories were created; and mathematical theories and experimental methods were adapted to engineering needs. The logical result was the emergence of engineering theories in addition to natural-scientific ones. The works performed within the walls of the Paris *École Polytechnique* specified the initial prerequisites for the formation of one of the first such theories, i.e., the theory of machines and mechanisms.

Natural science knowledge and laws can be used to solve practical engineering tasks only when they are significantly specified and modified within engineering theory. Thus, application cannot happen automatically; it requires the development of a special—engineering—theory. To bring theoretical knowledge to the level of practical engineering recommendations, this theory develops special rules that establish correspondence between the sphere of abstract objects described by it and the constructive elements of real engineering systems, and operations of transferring theoretical results to the sphere of engineering practice. Engineering theory is oriented not to explain and predict the course of natural processes but rather to construct engineering systems, remaining a theoretical study, even with certain specific features.

In classical scientific–engineering disciplines, engineering theory develops under the influence of a certain basic natural-scientific or mathematical discipline, from which it initially borrows theoretical schemes and models of scientific activity. For example, radio-engineering theory was based on the application and specification of the theoretical electrodynamic schemes of M. Faraday, J. Maxwell, and H. Hertz to solve the problem of wireless transmission of information. Since the initial theoretical schemes of natural science theory are subject to substantial modification, we should speak about the wide development of theoretical studies not only in natural but also in engineering sciences, as well as about the increased role of basic, theoretical, research, dictated by the needs of accelerating scientific–technological advance.

To specify regularities of the development of engineering knowledge, let us compare the contribution of G. Marconi and F. Braun to the development of radio engineering. Marconi's inventive contribution was minimal. Initially, he used scientific discoveries and technical results of other scholars and inventors in creating a useful and potentially profitable device, demonstrating his commercial skills. That was the final stage of scientific advance. Previously, the transfer of new knowledge took place exclusively in one direction: from science to engineering and then to commercial implementation. With time, however, the opposite information flow emerged, when Marconi, in targeting to reach as great a distance of wireless message transmission as possible, went beyond the sphere

[1] In Russia, the first higher engineering school, the Institute of the Corps of Railway Engineers, was founded in St. Petersburg in 1809 by the Spanish engineer A. de Betancourt (previously, a professor of the Paris *École Polytechnique*). As opposed to the *École Polytechnique*, which worked in the capital of France, in the Institute of the Corps of Railway Engineers, at Betancourt's suggestion, undergraduates were to devote their last year at the institute exclusively to practice. This institute had great influence on the development of engineering activity in Russia.

of knowledge in which science of his time could help him and began to study problems that had no ready answers from the existing theories [4, pp. 198–200]. That was a feedback process, the generation of new information from the sphere of experience that stimulated new scientific studies.[2]

On the one hand, the physical processes that took place in any new technical device required additional studies, but, on the other, it was becoming clear that the introduction of new appliances into commercial production and their subsequent spread in the market posed before the researcher and inventor tasks that went beyond the "discovery–invention–patenting" chain. The ability to unite all these spheres and to solve the entire scope of tasks was demonstrated by Braun, a brilliant theoretical physicist and, at the same time, a talented practitioner. He not only patented his inventions competently and in a timely manner but also created a firm for their promotion in the market, which later amalgamated with other businesses and began its production under the brand name of Telefunken [5, pp. 13–15, 19, 21]. We can consider Braun, who sought to bring radio engineering to the level of radio physics, as one of the creators of physical–engineering studies and physical–engineering education. This is the characteristic given to him by his students and our future Academicians L.I. Mandel'stam and N.D. Papaleksi, who continued his work on developing scientifically funded physical radio engineering [6].

Braun was the first to understand what specific electrical processes took place in the radio transmitter and radio receiver. Proceeding from theoretical considerations, he concluded that it was necessary to connect inductively the spark gap in the radio transmitter, as well as the coherer, with the antenna. This made his transmitter much more effective and thus made radio communication across the Atlantic possible. The cat's-whisker detector, invented by Braun, soon replaced the coherer proposed by the French engineer and inventor E. Branly. Mandelstam and Papaleksi noted the following [7]:

> The entire technique of transmission has undergone numerous changes since Braun implemented the closed loop into practice. The explosive spark discharge transmitter was replaced by M. Wien's transmitter after the fundamental discovery of the circuit spark .... The use of vacuum tubes led to complete modification and the emergence of perfectly new opportunities, which had hardly been imaginable in the first years of the development of this area.

(Note, however, that popular scientific literature usually says nothing about the role of Braun's discoveries [see, for example, 8, pp. 166–193].)

[2] In Russia, A.S. Popov experimented with the wireless transmission of signals in a similar way, but he did not find sufficient support from officials. Only later was the importance of his discovery for the country recognized: in Soviet Russia, both the radio industry and theoretical and applied developments in this sphere received serious state support.

"Wireless telegraphy" was initially an applied research trend in electrodynamics. Later it was considered as a new division (research area) of electrical engineering, aimed at struggling against various noises arising during the radiation, receipt, and use of high-frequency current. A significant part of early courses on radio engineering was devoted to electrical engineering, because radio engineering employed various standard electrical engineering devices and elements. Hence, radio-engineering circuits were initially considered as a kind of electrical-engineering circuits, working on high-frequency currents. In this case, we can speak about transferring the initial theoretical scheme and its respective notions, ideas, and analytical methods from the adjacent engineering theory. Thus, theoretical radio engineering formed along two main lines: first, specifying the theoretical scheme of electromagnetic interactions, developed by the basic natural-science theory (electrodynamics), when the range was filled with the values of practically used radio waves, and, at the same time, methods of studying their physical properties were being developed; and, second, through generalizing partial theoretical models that had resulted from analyzing the designs of various radio-engineering systems in solving specific engineering tasks.

The history of theoretical radio engineering is a model example (an historical ideal type) of the way of forming an engineering theory under which the initial point, on the one hand, of the development of new equipment and a new industry and, on the other, of an engineering theory and a scientific–engineering discipline, is interaction between natural-science theory and experiment in physics. This interaction provided a powerful impulse for the elaboration of radio engineering theory, without which it would have been unthinkable to solve modern engineering tasks, for example, on calculating and designing nonlinear radio engineering systems. Radio engineering practice posed difficult questions that could not be answered without turning to theoretical studies. In particular, this was the case during the transfer to the use of new wave bands and the creation of new radio electronic equipment or during the development of a new element base. The introduction of vacuum tubes, then semiconductors (for example, transistors) and solid-state circuits, and lately nanoelectronics into radio electronics has always been accompanied not only by building a new theory of these elements[3] but also by

[3] For example, in vacuum tubes, we consider the flight of electrons in the free space between the cathode and the anode and the effect of the grid on it, and not the movement of electric current in the conductor, or the distribution of magnetic and force lines. Consequently, a theory that is alternative to the electrodynamics of Faraday–Maxwell–Hertz, where the Newtonian principles of remote action operate, is rather applicable here. Thus, engineering practices require the coupling of seemingly theoretically incompatible pictures of physical reality.

the development of new methods of the analysis and synthesis of theoretical schemes.

As we see from the above examples, it is the informative, realizable in specific historical–scientific samples, methodological analysis of engineering (as well as natural-scientific) theories that allows us to understand better the real mechanisms of the functioning of modern science, the production of new scientific knowledge, and the interaction between science and engineering. This boosts the magnitude of the corresponding methodological studies of theoretical knowledge in engineering sciences for the philosophy of science and engineering. Such methodological studies are able to enrich philosophy, help substantially in understanding the problems that emerge at the front edge of scientific and technological advance, and also promote the effective influence of philosophy on the engineering and scientific thinking of representatives of various fields of science and engineering, on the norms of the organization of contemporary scientific and engineering knowledge, and, finally, on the governmental scientific and engineering policy. In this context, it is interesting to consider the recently originated sustainable trend of increase in the share of research in the philosophy of engineering in the total volume of works on the philosophy of science, in particular, in the sphere of science methodology—the growing number of studies on the methodological analysis of engineering sciences.

THE MAKING OF THE PHILOSOPHY OF TECHNOLOGY AS AN AUTONOMOUS PHILOSOPHICAL DISCIPLINE

The philosophy of engineering is the established name for an independent field of contemporary philosophical knowledge oriented toward the study of the most general regularities of the development of engineering, technology, engineering and technological activities, design, and engineering sciences, as well as their place in human culture in general and in contemporary society in particular; the relations between human beings and machines; the relations between machinery and nature; and the ethical, esthetical, global, and other problems of technological progress. The first publications on the philosophy of engineering appeared in 1877–1898 (E. Kapp, F. Bon, E. Zschimmer, F. Dessauer, and others in Germany and P.K. Engelmeier in Russia). In the 1900s and 1930s, within the philosophy and history of technology, there was an intense discussion of technological and cultural problems, as well as of the importance of these disciplines in the structure of engineering education. Another research trend in the theory of invention has born results that are still valuable nowadays. Note that societies of both countries participated in raising and discussing these problems: the Polytechnic Society, the Russian Technical Society, and the All-Russia Association of Engineers on the part of Russia and the Union of German Engineers, the Union of German Certified Engineers, and the Union of German Technicians on the part of Germany.

An important stage in the formation of the philosophy of technology as an independent philosophical trend came in the 1970s–1980s, when West German philosophers began to formulate a new research program in the philosophy of technology and published the collection *Techne, Technik, Technologie*, edited by professors H. Lenk and S. Moser of Technical University in Karlsruhe [9]. The results of the implementation of this program were summarized by the Georgius Agricola Society in a large-format ten-volume collection *Technik und Philosophie*, in which one volume was called *Technology and Culture* [10].[4]

The main problem in the consolidation of various studies and in the making of the philosophy of technology as an independent trend in modern philosophy was the distinction between its subject and the subjects of the history of technology, on the one hand, and the philosophy of science, on the other. Among the main indicators in the classification of works as belonging to the philosophy of technology and not to the philosophy of science or the history of technology is the inclusion into the circle of the topic under study of the methodology and history of engineering sciences. The history of technology, as a rule, has paid little attention to the development of the theoretical basics of technology and scientific–engineering knowledge, and the philosophy of science has been traditionally interested primarily in spheres that most affected the worldview and the scientific picture of the world, primarily theoretical physics and mathematics, and later biology. Engineering sciences in this respect have been considered to belong to the peripheral applied field of knowledge and have not received the attention of serious researchers in the philosophy of science. The situation changed only by the end of the 20th century, when society began to demand that science be more oriented toward engineering practice and even basic natural science began to be considered as the motor of engineering progress.

At the XIV International Congress of Logic, Methodology, and Philosophy of Science, which was held in

[4] An important role in the development of the philosophy of technology in Germany has been played by the Union of German Engineers (Verein Deutscher Ingeunieure, VDI), where the special research group called Man and Technology started working in 1956, which has the Philosophy and Technology working committee within its structure. Among the committee's main objectives are the study of the interconnection between contemporary technological development and its social consequences and the realization and interpretation on an interdisciplinary basis of the mutual influences of engineering, social, and cultural relations with a special focus on the fundamentals of engineering activities. In Russia, a similar role was played by the Russian Engineering Society and the Polytechnic Society, and later the All-Russia Association of Engineers.

July 2011 in Nancy (France), the methodological and philosophical problems of engineering won wide recognition for the first time in the history of this event. Note that the participants in the discussions were interested not so much in new achievements in technology as in the epistemological aspects of engineering knowledge. The discussion considered the content of the notion of "technoscience," the nature of the interaction between basic science and technology in postindustrial society, the notion of "design" and its role in applied research and technological developments, and the model of the interrelationship between basic and applied research. Thus, the main accent was, for the first time, made on the study of engineering and designing sciences and not on other philosophical problems of engineering and engineering development. As was stressed in the discussion at the symposium, nowadays it is impossible to ignore basic epistemological problems in engineering, engineering activities, and engineering sciences. The change in the attitude of philosophers of science to engineering disciplines was also reflected in the basic collective monograph *Philosophy of Technology and Engineering Sciences*, recently published in the series "Philosophy of Science" in Holland [11].

Unfortunately, works of Russian scientists on the philosophy of technology,[5] which are, in fact, even more progressive, are little known in the West, because in their overwhelming majority they have not been published in foreign international editions. In this respect, we should learn from the Dutch who recently have actively been entering the world arena, engaging their young specialists not one by one but as coordinated teams. In recent decades, they have published a series of collective monographs in English, engaging leading scientists from other countries. Even Germans, the acknowledged leaders in the philosophy of technology, have to consider the Dutch school and the new situation in philosophical science in general. Therefore, in recent years each research institute has allocated funds for translating German scientists into English, editing these texts by English speakers, and publishing them in peer-reviewed journals. Note that this practice covers all research fellows and not only the bosses and venerable specialists. The author of this article is also trying to follow the new principles of the international philosophical dialogue and, over the past five years, primarily thanks to close cooperation with the Institute of Technology Evaluation and System Analysis of the Karlsruhe Research Center (Germany), has published more than ten articles in English and German on problems of the philosophy of technology [12–20].

THE PHILOSOPHY OF TECHNOLOGY AND A NEW STAGE IN THE DEVELOPMENT OF ENGINEERING SCIENCES

In the first section of this article, we tried to show the characteristic features of engineering sciences and the process of forming engineering theories. The important point, however, is the study of contemporary trends in science and technology. If, for natural sciences, the purport of laws is directly proportionate to the degree of their general validity, for the cognition of historical events in their specific conditions, as M. Weber stressed, the most general laws, mostly deprived of contents, have, as a rule, the smallest purport [21]. Our meaningful–methodological analysis of the history of engineering sciences is based on the analysis of the history of science, which bridges the gap between philosophical reasoning, on the one hand, and the purely evidential description of historical–scientific facts, on the other.[6]

In recent decades, significant changes have occurred in scientific-engineering disciplines that allow us to speak about the making of a qualitatively new, nonclassical, stage of their development, which is characterized by new forms of organization of knowledge and activity. Nonclassical scientific and engineering disciplines differ from classical engineering sciences in the *complexity* of theoretical research, no matter which form of implementation it takes and how it is formed. In classical engineering sciences, theory was built under the influence of a certain basic natural-scientific discipline, from which theoretical means and samples of scientific activity were borrowed at the initial stage, while many contemporary scientific-engineering disciplines have no such single basic theory, because they are oriented at solving complex scientific-engineering problems. Simultaneously, new specific methods and means are developed within them, which are absent in any of the synthesized disciplines and which are specially adapted for solving a given complex scientific-engineering problem. Therefore, classical engineering sciences are *subject oriented* toward a certain class of engineering systems (mechanisms, machines, radiotechnical devices, radars, etc.), and complex scientific-engineering disciplines are *problem oriented* toward solving a certain type of complex scientific-engineering problems, although the objects of their research may partially coincide. This

[5] The sector of the philosophy of technology was established at the RAS Institute of Philosophy as early as 1988. Later it was transformed into a working group, which is now part of the sector of interdisciplinary problems of scientific and technological development.

[6] It was most influenced by the works of Academician V.S. Stepin on the meaningful–methodological analysis of the development of scientific theory in classical and nonclassical natural science by the example of electrodynamics [22, 23]. This perennial research resulted in books and textbooks published under the aegis of the RAS Institute of Philosophy [24–27].

differentiation into classical and nonclassical scientific-engineering disciplines is rooted in the development of engineering activity itself and designing. In a certain framework, the traditional spheres of scientific research and engineering practice continue to function and solve specific scientific and technical problems; however, it is very important to picture what this framework is like and what limitations it imposes.

Technoscience, which is being formed at the beginning of the 21st century, represents a symbiosis of natural and engineering sciences; therefore, the methodological distinctions obtained previously after the analysis of both fit well into the empirical material, new for the philosophy of science. Basic research in natural science is becoming increasingly more problem and project oriented, aimed at solving specific scientific-engineering problems, making it very similar to engineering science and finding its expression in defining this new stage in the development of science as a stage of technoscience, the most brilliant representative of which is nanotechnology.

Nanotechnology is recognized today as a key scientific sphere not only because it leads to a change in the entire scientific-engineering landscape but primarily because society awaits positive economic, environmental, and social results in the very near future. Nanotechnology may serve as an informative example of several new philosophical–methodological problems associated with the coalescing of science and technology and requiring special analysis. In nanotechnology, research is often initiated by an engineering task, having a project form, and, in fact, being problem oriented. As an example, we may mention research into the chemical nanoassembly of transistors from carbon nanotubes to obtain a more complex nanostructure. The chief problem here is to bind individual nanotubes into a nanocircuit and to visualize this nanocircuit for measuring the input and transfer characteristics of the nanotransistor obtained [28, pp. 77–94]. Thus, the research problem is determined by an engineering task, since a transistor is an important component of the electronic industry, and in this case, it is simultaneously an object of research. To achieve its greater miniaturization, a goal that is, in fact, dictated by the social order, it is required to develop ever-new technologies and materials among which transistors made from carbon nanotubes are considered the most promising. The binding of carbon nanotubes among themselves into a functional circuit is also an exceptionally complex engineering task.

In technoscience, scientific research is practically always accompanied by computer simulation, and what we see on the display screen has already been mediated by one theory or another, which served as the basis for a given measuring system, and its mathematical assumptions, "wired" into the program of simulation modeling. In technoscience, differences between natural-scientific and engineering theories blend almost fully, since a natural-scientific experiment becomes inseparable from designing, and the results of such research are aimed simultaneously at explaining and predicting the course of natural nanoprocessors, as well as at designing new artificial nanostructures. On the one hand, nanotechnoscience builds explanatory schemes of natural phenomena based on mathematical assumptions and experimental data and formulates predictions of the course of certain natural processes, and in this part, it reproduces the methodological principles of classical natural science. On the other hand, similarly to how it happens in engineering sciences, it constructs not only the designs of new experimental situations but also the structural schemes of nanosystems unknown in nature and technology.

Another trend in the development of engineering sciences is associated with the powerful growth in the science intensity of technologies, which cannot be compared with traditional handicraft technologies any longer. Nano-, bio-, info-, and cognitive technologies break into the social, biological, and psychical spheres of human life, producing corresponding philosophical discussions as a natural result. Inside the scientific-engineering community itself, the demand emerges for understanding processes that are generated in our society by new technologies and their positive and negative consequences. Therefore, even in monographs and at conferences dedicated to narrowly specialized problems, we can observe still humble attempts to discuss the deep social, philosophical, and epistemological issues of technological progress. Numerous publications have appeared in which specialists analyze such topics within various engineering sciences, although previously such investigations were the prerogative of professional philosophers.

At the same time, new science-intensive technologies have become so complex and multifaceted that neither narrow specialists nor philosophers are able to comprehend them independently. Specialists who involuntarily and inevitably intrude into the sociohumanities sphere with their innovations lack the culture of the humanities and the knowledge of the philosophical tradition for discussing and analyzing engineering and technological innovations, whereas philosophers, with few exceptions, lack even a perfunctory understanding of the mechanisms of the development of new technologies.

Thus, a hard-to-solve dilemma arises to bridge these two worlds, which are somewhat incompatible with each other. The introduction of a "History and Philosophy of Science" course for postgraduate students of all specialties, which also includes the philosophy of technology, is partly an attempt to overcome the existing gap; however, in practice, the philosophy of technology is often considered as necessary reading only for those who specialize in engineering sciences.

Such an approach is wrong in principle, first, because technology largely determines our way of life today and, second, due to those changes that scientific endeavor itself undergoes. As for the philosophical analysis of engineering sciences, it still lacks validity and ties to specific historical realities, and this also hinders bridging the gap between the philosophical and narrowly specialized views on problems of contemporary technological development. Many researchers avoid the comprehensive study of science and technology, which implies reference to scientific-engineering disciplines and technical theories, preferring to limit themselves to the assertion of the fact that "the majority of engineering sciences have their own theories" [29, p. 3] and that "they are in-between mathematical and natural-scientific theories and engineering practice," including "elements of deductively axiomatic theories" [30, pp. 110, 114, 118].

We may conclude that the rapid progress of science and technology poses anew many old philosophical problems before scientists and brings to the fore a number of new methodological, social, cognitive, and other issues and collisions, the understanding of which requires a high philosophical level. Scientists are unable to comprehend these problems without philosophers. However, the philosophers of science and technology will not cope with this task without close cooperation and dialogue with scientists that are experts in the subject matter.

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