

9th International Scientific Conference on Defensive Technologies OTEH 2020

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The paper describes the activities of the ninth scientific conference of researchers who are engaged in defensive technologies, which was organized by the Military Technical Institute and held in October 15-016, 20120, in Belgrade. This year, for the first time, OTEH 2020 was held according to the online concept where the organizers showed their capability of coping with all the difficulties the COVID-19 pandemic had caused.

Introduction

TRADITIONALLY, at the beginning of October, in Belgrade, SERBIA, the Military Technical Institute (VTI) held the International scientific-technical conference in the area of defensive technologies OTEH 2020 for the ninth time. As well as in previous years, the organizer of this scientific conference was VTI, a scientific research institution more than seventy years (founded in 1948) of tradition in development of weaponry and military equipment.

By now the Institute developed and adopted around 1400 combat and non-combat systems into the operational use with which, together with the Serbian Army, many foreign armies are equipped as well.



Figure 1. OTEH International Scientific Technical Conference

Realization of the conference

OTEH is a highly important international scientific-technical manifestation which is regularly held every second year and which comprehensively and multidisciplinary considers current situation and further development trends in the area of military technical sciences.

During two days of conference duration a great number of quality and authentic papers was presented, which originated out of the current projects researchers are

working on, as well as the papers which already have a practical use or at least refer to assumptions and further development trends of certain military technologies areas. This year, for the first time, OTEH 2020 was held according to the “online” concept due to the COVID-19 pandemic. The organizers were very successful in coping with all the difficulties they have stumbled upon during their work and showed great adroitness in various situations, the corona pandemic in this case.



Figure 2. OTEH 2020 opening day

OTEH 2020 had 152 submitted papers out of which 94 were accepted and included in the programme. 77 papers were from Serbia, 17 were from abroad (14 countries in total). The papers were classified into eight topics; Aerodynamics and Flight Dynamics (8), Aircraft (14), Weapon Systems and Combat Vehicles (5), Ammunition and Energetic Materials (5), Integrated Sensor Systems and Robotic Systems (11), telecommunication and Information Systems (11), Materials and Technologies (34), as well as Quality, Standardization, Metrology, Maintenance and Exploitation (6).

The exchange of knowledge the OTEH propagates deepens the international cooperation in the area of education, research, development and production of armament and military equipment. The international character of this conference is confirmed from year to year, especially when it is successfully held in situations like COVID-19 pandemic. Together with

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domestic, foreign authors and coauthors participated with their papers. There were 17 scientific papers from 14 foreign countries. Foreign authors and coauthors were from: Slovenia, Republic of Srpska, Bosnia and Herzegovina, Algeria, Finland, Lithuania, Bulgaria, Libya, Belarus, Portugal, Germany, United Kingdom, India and Croatia.

International Scientific Technical Conference OTEH 2020 has intended to provide opportunities for scientists and engineers, researchers, designers and university community from many countries to share ideas and technical information, as well as to build new relationships. During two online days of the conference, participants could have asked the questions, set remarks or even contact the authors through their emails.

The Conference was opened by the Military Technical Institute Director, Colonel Bojan Pavković, PhD Eng, who after wishing a warm welcome and successful work, emphasized that “only a constant development of new defense technologies can support even stricter requirements of designing the state-of-the-art AME (armament and military equipment) systems. It is a complex process requiring cooperation of institutes, faculties and factories, as well as a comprehensive and systematic approach of the highest state authorities and institutions. The exchange of opinions and experiences and comparing the achieved results to other similar institutions in country and abroad present a certain path to success and progress. That is actually the main reason of our gathering at the international scientific technical conference. It is my pleasure that this year, even beside the epidemic situation, a significant number of participants responded to the call for papers, which raised the quality of the conference to a higher level. I expect the technical problems considered in the papers will have a practical use in the areas that are significant for defense industry and the Serbian Armed Forces”.



Figure 3. One of many presented scientific papers at OTEH 2020

After the opening speech and general presentation of this event, we had two introductory lectures—which admittedly attracted a lot of interest. Since this year OTEH was dedicated to Mihailo Petrović Alas, a famous Serbian mathematician, the lecture on that occasion was given by professor Željko Mijajlović, PhD, from the Mathematical Institute of SASA (Serbian Academy of Science and Arts). The other lecture was given by professor Momčilo Milinović, PhD Eng, from the Faculty of Mechanical Engineering in Belgrade on new trends in contemporary armament. The lecture was titled “Electromagnetic Pulsed Weapon Treat HMP and HEMP – new world disasting challenge of direct energy weapon from the space”.

Mihailo Petrović Alas

In the second half of the 19th century the foundations of contemporary mathematics were laid. The most influential mathematicians of the time, Henri Poincaré and David Hilbert introduced new mathematical concepts and a new style of abstract mathematical thinking. New mathematical theories with multiple applications in technical engineering and physics were emerging and old theories were receiving new groundings.

Mihailo Petrović, Poincaré’s direct student, began his academic career equipped with such knowledge and the understanding of science and culture that existed in Europe at the time. As a young man, he was already a well-formed mathematician and highly prolific academically. He was well familiar with the works of French mathematicians, examining the most topical issues on differential equations and the theory of function.



Figure 4. Mihailo Petrović – Mika Alas (academician, 1899.)

Mihailo Petrović was born on April 23rd, 1868 (Julian calendar) in Belgrade, to a reputable family, of mother Milica and father Nikodim. His father earned a doctorate in theology in Kiev and taught theology at the Belgrade Faculty of Theology. As Nikodim died young, Mihailo barely remembered him. Mihailo’s maternal grandfather, parish priest Novica Lazarević took care about his grandson and his education. They were very close. Mihailo completed the First Belgrade Gymnasium in 1878-85. His school peers were Milorad Mitrović, Jovan Cvijić, Pavle Popović and others, who later became important figures of the Serbian culture and science. He already then showed interest in mathematics, winning awards for his term papers and attracting his professors’ attention with his talent. He enrolled in the Natural Science –Mathematical Department of the Belgrade Faculty of Philosophy. He graduated in 1889 and soon went to Paris for specialization and further studies of mathematics.

After arriving in Paris he underwent one-year preparations for the entrance exam for the prestigious L'École Normale Supérieure. Petrović passed the exam with distinction, gaining the privilege to study at the Collège de Sorbonne, the best European school of mathematics at the time. At Sorbonne, he first graduated from chemical sciences in 1891, from mathematics in 1892 and then from physics in 1893. As the best student in his generation, he was received by the President of the French Republic, both in 1893 and 1894. He enrolled in doctoral studies at the same University. He defended his doctoral thesis *Sur les zeros et les infinis des intégrales des équations différentielles algébriques* in 1894 in the field of differential equations (Riccati equation). The examination committee consisted of the time, Charles Hermite, Emile Charles Picard and Paul Painlevé.

When Mihailo Petrović returned from Paris to Belgrade in 1894, his erstwhile professor Dimitrije Nešić retired. Petrović applied for the vacancy of a professor at the Great School, together with Petar Vukićević, his somewhat older colleague from the Belgrade Faculty of Philosophy.

Petrović was chosen for the post, after getting one vote more than Vukićević. Vukićević subsequently became a gymnasium professor and, probably under the influence of his defeat at the contest, no longer dealt with science or pursued the academic career. At the time the Great School consistently applied the *numerus clausus* principle, limiting the number of teaching posts and often to the detriment of the development of Belgrade Grand School. Regarding his election for the post, Petrović once said: "Had I not obtained that additional vote at the competition for the Great School professor, I would have never dealt with mathematics. I would have lived on the Serbian rivers, not on a boat, but in a dinghy."

Upon his return to Belgrade, Petrović encountered several mathematicians who were engaged in scholarly work: Ljubomir Klerić, Dimitrije Nešić, Petar Živković, Dimitrije Danić and Bogdan Gavrilović. Among them, Professor Bogdan Gavrilović held in particularly high regard and he soon became a close friend and fellow colleague of Petrović. Gavrilović was, among other things, a writer of excellent university textbooks on linear algebra and analytical geometry, about which Radivoj Kašanin said the following: "Both textbooks, but particularly the latter one, would have been to the credit of every nation and at that time many nations far bigger and happier than us did not have such works". At approximately the same time two other scholars with PhD in mathematics were also residing in Belgrade, namely Đorđe Petković and Petar Vukićević, who pursued their careers as gymnasium professors.

In his scholarly work, Mihailo Petrović upheld the highest standards of the most developed European countries. During a brilliant upward career span, in only four years, by the beginning of the 20th century, Petrović published some thirty papers in leading European mathematical journals. This success has brought a great reputation to Petrović and he soon received a major recognition. Already in 1897, less than thirty years old, he became a correspondent member of the Serbian Royal Academy and in 1899 a regular member. He became an honorary member of several foreign academies of art and sciences, namely those in Bucharest, Prague, Warsaw and Krakow. He was elected correspondent member of the Yugoslav Academy of Sciences in Zagreb and became a member of numerous European learned societies.

In terms of his academic work, Petrović belongs to a

specific time. Due to the rising size of the mathematical knowledge, it was difficult, if not impossible, for an individual to be well acquainted with all the mathematical knowledge. The time of universal mathematicians and scientists was slowly passing. Henri Poincaré was one of last *homo universalis* of science in the sense of the understanding and breadth of academic work in mathematics, mechanics and philosophy and he was one of professors of Mihailo Petrović. Judging by his later scholarly work, we can conclude that the spirit of universalism of his professors inculcated Petrović as well. He equally excelled and achieved first-rate results in several mathematical fields: differential equations, numerical analysis, theory of functions of a complex variable and geometry of polynomials. His interest also expanded to natural sciences, chemistry, physics and biology. Petrović was a founder of new academic disciplines, mathematical phenomenology too.

The influence of Mihailo Petrović on the development of mathematics in Serbia was enormous. He was *spiritus movens* of Serbian mathematics and has strongly contributed to the spirit of contemporary European science in Serbia. Moreover, he knew how to gather people together, awaken their interest and motivate them. This is solely an option of Serbian mathematical public, but also the fact established in word-class reference journals. Thus *The Oxford handbook of the History of Mathematics* gives prominent space to academic biography of Mihailo Petrović. It emphasizes that Petrović, as the most prominent Serbian mathematician at that time, set direction of development of Serbian mathematical school on the grounds of the French mathematics.

In his academic career, Petrović published some four hundred papers, of which three hundred in mathematics. Furthermore, he published twelve books and there are fourteen manuscripts on the basis of his lectures, made either by students or himself. The academic career of Mihailo Petrović was tied to the Grand School which became a University in 1905 and subsequently to the University of Belgrade, until the end of his professional life.

As he once said himself, he had spent a total of fifty years in Mansion of Miša Anastasijević, where the gymnasium he attended was located, along with the Grand School, first as a pupil and later as a student and a professor. The Department of Mathematics of the Faculty of Philosophy was the main site of the Petrović's scholarly and pedagogical work.

He has published three university books: *Computation with number intervals* (1932), *Elliptic Functions* (1937) and *Integration of differential equations using series* (1938). He also published the textbook *Leçons sur les spectres mathématiques*, Paris (1928), which he followed when he gave lectures at Sorbonne in Paris in 1927-1928. When we talk about Petrović's teaching work at the University, we have to say that along with his colleague, Professor Bogdan Gavrilović, Petrović has elevated Serbian mathematics to the European level. Milutin Milanković emphasizes that the two of them have laid the foundations of Serbian mathematics. Petrović has done it in terms of academic work and Gavrilović in terms of organizational work, helping the Grand School to grow into the University of Belgrade. Gavrilović was close to the royal family, while Petrović was not, primarily due to his friendship with Prince Đorđe Karađorđević, who fell out of grace with the King. Consequently, Gavrilović was the rector of the University of Belgrade and president of the Academy (1931-1937), while the candidacy of academic circles of Petrović for this

position in 1927 and 1931 was not accepted or approved by the authorities. Most authors attribute this to King's animosity towards him. However, it has to be said that Mihailo Petrović did not encounter obstacles in his academic work or any other activities. On the contrary, he enjoyed great reputation, both among the general public and among government representatives as a great scientist and a great expert. He was engaged in important state commissions, for example he was the main cryptographer of the Serbian and Yugoslav army and represented his country in international commissions and delegations in the areas of education and fisheries. It is possible that his unconventional life has contributed to the failure of his nomination to become the rector and the president of the Academy.

Similarly to mythological divinity Janus, Mihailo Petrović had two faces. One was turned towards mathematics, philosophy and the spiritual work, the other looked towards faraway roads, fisherman's adventures and tavern gatherings. It is possible that some part of the government could not reconcile this other side of Petrović with the image of a chancellor who almost daily wades in his fisherman's boots through the Danube backwaters, hunting for fish and subsequently playing violin to entertain folks in tavern. However, there are anecdotes that also suggest that even gentlemen of the highest station at the time were not able to resist the charm of "a fisherman's ball" which Petrović was often organizing. Jelenko Mihailović, his friend, recorded an anecdote from around 1904 involving the famous Finance Minister Lazar Paču and Mika's great catch, a beluga, "weighing 200 kilos". Even though the Minister received 10 kilos of "caviar from this catch it was not enough and the same evening he brought the entire government, headed by the Prime Minister to tavern "Jasenica" to have dinner prepared by Mika Alas. The posts of the chancellor and the president of the Academy, even though they are high positions, are nonetheless only administrative positions and Petrović did not much regret not occupying them. It is possible that he himself did not want to take on that kind of responsibility because it would interfere with the life he was leading and loving. Notwithstanding the aforementioned differences, Petrović and Gavrilović shared the same love for science, students and university. They were colleagues and together with Milutin Milanković the bedrock of the Mathematical Club between the two World wars.

The words of Radivoj Kašanin, Petrović's doctoral student and Gavrilović's assistant and heir at the Mathematical Department of the Faculty of Technology, can also serve as an illustration:

"In addition to their high educational qualifications and original academic work, the three of them had also possessed a feature I appreciate most and consider a human quality of the highest rank: appreciation of younger generations, understanding of young people, selfless and sincere assistance to the young, talented people in their advancement. They knew how to rejoice and enjoy when young people rise to prominence.

I was lucky to develop and work alongside these great authorities in science and morality. To take pride in their friendship. I do not believe that anywhere else there existed such an atmosphere as the one that was created by Gavrilović, Petrović and Milanković."

In the meantime, science at the University of Belgrade became so advanced that the first doctoral dissertations in mathematics were defended at the University, under the

supervision of professor Petrović. A PhD in the field of differential equations was defended in 1912 by Mladen Berić, a teaching assistant to professor Mihailo Petrović. Already, the following year, Sima Marković defended his PhD on the topic of Ricatti differential equation. This has marked the emergence of the Belgrade Mathematical School. Sadly, the work at the University of Belgrade has often been interrupted due to wars. In academic year 1912/13 the University was closed due to the Balkan wars. In academic year 1913/14 the University reopened, but the First World War interrupted its work again and student and professors had to go to war. Soon after he war started, a part of the Mansion of Miša Anastasijević was torn down due to bombing. The enemy ransacked the deserted and demolished building. Mihailo Petrović participated in the war as a reserve officer.

When the war ended in early 1920s, the University experienced an accelerated growth for a short period of time. The number of professors increased and among others, mathematicians Nikola Saltikov and Anton Bilomović came from Russia, giving a strong boost to the Department of Mathematics at the Faculty of Philosophy. Even though Mladen Berić and Sima Marković were gifted mathematicians and became lecturers at the Department of Mathematics, they left the University already in mid 1920s. Berić had private reasons to do so, while Marković had to leave because of politics (he founded and was one of the first leaders of the Yugoslav Communist Party. However, he was killed in Stalinist purges in 1939). Even though professor Petrović placed his hopes on his best students, he did not have luck with them.

The mathematical descendants of Professor Mihailo Petrović, connected with him through his supervision of their PhD theses, constitute mathematical genealogy tree made up of around 800 mathematicians. Of that number, around 500 are Serbian mathematicians, the rest are foreigners. If we look closely at the tree, we will notice four major clusters, the roots of which are made up of: Tadija Pejović, Jovan Karamata, Dragoslav Mitrinović and Konstantin Orlov. They have merits for introduction of new fields of research in Serbian mathematics or creation of their own mathematical schools. Thanks to the endowment by Luka Čelović Trebinjac and at the initiative of Anton Bilinović, with the support of Mihailo Petrović and Milutin Milanković, a new journal was launched in 1932 entitled *Publications de l'Institut Mathématique Université de Belgrade*. The papers were published in Russian, English, French and German. Belgrade mathematicians have thus gained a possibility to present their academic papers to worldwide mathematical public.

At the very beginning of the 20th century, Petrović expressed great interest in the practical side of mathematics. He was deeply preoccupied with the problem of the appearance and manner of appearance of mathematics in natural sciences, that is, the way in which mathematics can be applied to a research of natural phenomena. Similarly to Leibnitz, who tried to invent *characteristic universalis*, a universal and formal language that would be able to express all mathematical, scientific and metaphysical notions, Petrović tried to invent a universal method that would be used to solve problems in other sciences. The fundamental place in his discussion was accorded to analogies. He was searching for and citing examples of completely disparate phenomena that can be described by same differential equations. These efforts have produced an original work he is noted for – namely, mathematical phenomenology. He has

published three books on the topic, two in Serbian and one in French, presenting his theory.

Mihailo Petrović retired in 1938 and has been given with the highest accolades by his students and fellow colleagues. The following year, he received an honorary doctorate of the University of Belgrade and was decorated with the Decoration of St. Sava of the first degree.

The proposal submitted to the Council of the Faculty of Philosophy to award the honorary doctorate to Petrović emphasizes his achievements in the creation of the mathematical school in Serbia. At the same time, members of the Mathematical Seminar have made a proposal to single out a section for theoretical mathematics and name it *The Institute for Theoretical Mathematics Mihailo Petrović*. In the justification of the proposal they wrote: "Our Mathematical Seminar is eternally grateful to him, because he was its founder and worked and developed in this Seminar for 44 years. He managed to gather together at this Seminar a large number of young people and to prepare them for an academic work".

Petrović's activities related to military sciences

Petrović bore a high military rank of a reserve officer, he was an engineering lieutenant-colonel in the reserve. When German forces attacked Serbia in April 1941, he was drafted although he was 73 at the time. He was immediately arrested and has spent one year in captivity. In the military sciences and its domains, Petrović had significant contributions that were used in the Serbian and Yugoslav armies. He was the main cryptanalyst of the Serbian, then

Yugoslav army from the beginning of the 20th century until the Second World War. He left ten his own patents, most of which are of the military nature. In fact, he had more inventions, of which the most famous (unpatented) is hydrointegrator, an analog computing machine for solving differential equations.



Figure 5. Hydrointegrator drawing

Table 1. Patents of Mihailo Petrović – Mika Alas

No	Patent number	Patent original title	Application date	Patent verification date	Patent joint owner	Patent application country
1	FR 413.730	Télémetre a sextant	11.02.1910	17.08.1910	Milorad Terzić	France
2	FR 447.861	Chagement de vitesse avec pignons étagés recordés par des engrenages en hélice conique	31.08.1912	17.01.1919	Svetolik Popović	France
3	FR 463.082	Chagement de vitesse	29.09.1913	13.02.1914		France
4	FR 476.320	Automatique chagement de vitesse	17.10.1914	27.07.1915		France
5	FR 480.788	Cadran calendrier pour objets d'horlogerie, de bijouterie et autres	27.01.1916	21.09.1916		France
6	FR 515.072	Dispositif pour assurer la flottabilité des navires en danger	24.11.1917	24.03.1921		France
7	FR 493.774	Appareil pour la détermination rapide des elements de tir sur aéronefs	07.12.1917	21.08.1919		France
8	FR 495.040	Moteur	15.02.1918	26.09.1919		France
9	FR 503.321	Appareil imprimant un mouvement rapide aux bombes, mines aériennes et torpilles aériennes lancées par un canin lisse	22.02.1918	08.06.1920		France
10	GB 121.279.	Means for Assuring the Buoyancy of Ships	23.10.1918			Great Britain

Patents

It can be said that some Petrović's works highly contributed to the progress in Serbia not only in mathematics but in technical sciences as well Petrović has primarily been celebrated as a mathematician, whereas the promotion of his numerous ideas and achievements in other various fields has been somewhat neglected.

Petrović begun to be interested in the practical side of science already during his stay in Paris (1889-1894) where he acquired his basic knowledge not only in mathematics, but also in other sciences, primarily physics. In his practical work, as he himself pointed out in several occasions, Petrović was

inspired by natural philosophy, in particular mathematical phenomenology. In this respect, inventions and patents for him were the example of materialized idea.

Cryptography

There are no explicit records on Petrović's cryptology. This is not surprising as the works in this area between the two world wars were considered a military and state secret. Petrović's achievement in cryptography have been documented in 15 volumes of the Cipher Bureau of the Intelligence Unit of the Armed Forces Genera Staff of the

Kingdom of Yugoslavia, under the title *Kriptografija – škola za obuku na šifri* (Cryptography: Code School), and in 24 volumes *Sistem (za šifrovanje)* (Coding System). Based on those documents, the work of Petrović and the ensuing results can be found in the following areas:

- The methods for encryption
- The methods for “breaking” the codes and
- Educational materials related to the techniques for enciphering and deciphering the encrypted messages.

Mihailo Petrović had a rich, interesting and unconventional life. It is hard to enumerate in one place, let alone describe in detail everything that he engaged in. Besides tackling various mathematical issues, Petrović was present at many other, often unexpected places. He was the author of laws and proposals of intergovernmental agreements and the inventor and owner of successful and implemented patents.

Many consider Mihailo Petrović Alas one of our most important philosophers and the creator of the original theory in natural philosophy – mathematical phenomenology. He wrote in a nice and interesting way, and some of his novels became a part of obligatory school reading and belonged, as they do today, to favorite youth literature. In addition to novels, he wrote essays and travelogues and was an associate of daily papers.

He wrote scientific paper and was also interested in other natural sciences, primarily astronomy, relativity theory and chemistry. He created the cryptographic system and was the main cryptographer of the Serbian and Yugoslav armies. He played the violin and led the music company “Suz”, which had one of the leading roles in Belgrade’s bohemian life until the start of the World War II. He also collected folk poems and folklore elements. Finally, he was a passionate fisherman and a great world traveler and seafarer on northern and southern seas.



Figure 6. Mika Alas in a tavern playing the violin (he is the one with a hat)

This great mathematician passed away silently, dreaming about a new and great oceanic travel. Mihailo Petrović Alas died in Belgrade on June 8th, 1943 in his home on Kosančićev venac 22. Many Serbian and several foreign authors have written about the work and life of Mihailo Petrović.

Conclusion

Looking back, it can be said that OTEH 2020 has fulfilled the aims which were assigned. There are many challenges we face and the road is long, with many winding turns. Our community is strong, skillful, dedicated and eager to succeed. Together we can and we will make a difference. We hope that many friendships and cooperation will grow from contacts made at the OTEH 2020 conference. During the two-day Conference, many high-quality and original papers from current research projects were presented, as well as the papers on the research already applied in practice in particular military technology areas.



Figure 7. VTI Headquarters

Next OTEH Conference will be held in Belgrade in 2022. We have a great pleasure to invite all of you to participate at the 10th OTEH. We must do even better in the future. Increase the value extracted out of the research and development investments, using the opportunities the OTEH is providing in terms of synergy and accessibility.

Specially thanks to all the participants that were involved in OTEH 2020 organization and especially to our foreign guests. We also want to thank all authors and participants who have shared their work and ideas with us.

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9. Međunarodni naučnostručni skup iz oblasti odbrambenih tehnologija OTEH 2020

Ovaj rad nudi opšte informacije o 9. Naučnostručnom skupu OTEH 2020 organizovanom od 15-16 oktobra 2020. godine u Vojnotehničkom institutu u Beogradu. Ove godine, po prvi put, OTEH 2020 realizovan je u skladu sa online konceptom pri čemu su organizatori pokazali sposobnost da se izbore sa poteškoćama uzrokovanim pandemijom virusa COVID-19.

Cljučne reči: odbrambena tehnologija, vojna industrija, međunarodni naučni skup, Srbija.