monthly scientific and technical journal SITK RP sp. z o.o.

transportation® overview

2
2026
year LXXXI
price 36,00 zł
including 8% VAT

PUBLISHED SINCE 1945

Space technologies 2

eISSN
2544-6037

ISSN
0033-22-32

INFORMATION ABOUT THE SERIES "SILHOUETTES". The space sector in the state defense and security system. Strategic analysis and recommendations for action. A new decade of Polish presence in space. Innovation Forum, December 2025. Poland after world war III. MIRORES: MIR/FIR Space Spectrometers for Lunar and Terrestrial Geological Prospecting. Space age education

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In this issue

In the first issue of Przegląd Komunikacyjny devoted to space technologies (No. 7-8, 2025), we presented the origins, purpose, and activities that led to the creation of the National Committee for Space Technologies. This issue of the monthly magazine contains strategic articles on the space sector. Due to the turbulent international situation and the growing role of space issues in current armed conflicts, the issue opens with an article by General Lech Majewski on military issues, which is obvious given the author's connections with, among others, the National Defense Academy and the Air Force Institute of Technology. The second strategic text is by Professor Grzegorz Wrochna, the current Director of Creotech Instruments. The texts written by these eminent experts are particularly noteworthy, especially since both authors have managed the Polish Space Agency in the past. The development of the domestic industry was discussed at the last industry conference in 2025 – the Innovation Forum, which took place in Wrocław on December 3-4 with the participation of, among others, Mr. Artur Chmielewski from JPL/NASA. The issue also includes a geopolitical article that looks even further into the future. The topic was presented during the G2 Forum in 2019-2025, in the space panel, during which the need for close cooperation between the Three Seas countries and the Scandinavian countries was demonstrated, which is now beginning. Another article presents the work of a team associated with the Polish Academy of Sciences, referring to the practical applications and commercialization of knowledge. This issue concludes with a description of school-level education in robotics and space technology, which has been implemented for years in Lower Silesia. The issue also presents two personalities from the space industry.

Piotr A. Wrzecioniarz

In the journal

Basic information for article authors

"Transportation Overview" publishes articles related to broadly understood transport and transport infrastructure. Detailed information on receiving applications, advertising and subscriptions is available at: **www.transportation.overview.pwr.edu.pl**

Publisher:
Department Board, ul. Marszałka Józefa Piłsudskiego 74, 216, 50-020 Wrocław
Leszek Krawczyk - Prezes
sitk.pkpik.pl

Partner:
Adam Bisek: designer, inventor, entrepreneur and author of many innovative technologies and implementations, visionary with a great passion for aviation and astronautics, winner of many prestigious awards and decorations, including Outstanding Engineer, Honorary Golden Engineer, Blue Wings, Golden Lotto, Diamond Lotto - Polish delegate to the UN for space development, organizer of 5 astronaut conventions.

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Declaration of the original version of the journal
The main version of the journal is the electronic version. Full versions of articles with summaries in Polish (since 2010) and English (since 2016) are available on the journal's website. The editors reserve the right to make changes to materials that are not subject to review.

Articles published in "Transportation Overview" are available in the databases of 20 technical libraries and are indexed in the following databases:

BAZTECH: **http://baztech.icm.edu.pl**
Index Copernicus: **http://indexcopernicus.com**
International base DOAJ **https://doaj.org/**

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Details and order form on the website:
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The current Editorial Office has archive issues since 4/2010.
Archive issues from 2004-2009 can be ordered at the Krakow department SITK, ul. Siostrzana 11, 30-804 Kraków, tel./faks 12 658 93 74, **mrowinska@sitk.org.pl**

Printing:
Intromax Sp. z o.o, ul. Biskupińska 21, 30-732 Kraków, http://www.intromax.com.pl/
Print run: 800 cop.

INFORMATION ABOUT THE SERIES "SILHOUETTES"

In the series "Silhouettes" we will introduce selected representatives of our industry. The descriptions will be prepared by those directly involved. In the descriptions, special emphasis will be placed not on scientific achievements, but on practical implementations, impact on the local and regional as well as national and, if possible, international environment, and impact on society.

The editors reserve the right to make appropriate abbreviations. In the first issue, we present the profiles of the General Lech Majewski and Prof. Jan Dziuban.

Retired Lieutenant General, pilot Lech Majewski

Academic Center for Strategic Analysis
War Studies University

Graduate of the Higher Officer Aviation School, Aviation Academy, General Staff Academy of the Polish Armed Forces, National Defense University in Washington, D.C., and domestic and foreign specialist courses and training programs. He flew MiG-29, MiG-21, MiG-15, TS-11, TS-8, and M-28 aircraft, as well as familiarization flights on F-18, F-16, Mirage-2000, Mirage-2005, T-38, and M-346 aircraft.

Former Commander-in-Chief of the Armed Forces, Polish Air Force, Air Operations Center in Warsaw, 3rd Air Defense Corps in Wrocław, 1st Fighter Aviation Regiment, Vice President of the Polish Space Agency, Director of the Export Division at ELEKTROTIM S.A., Ministry of National Defense Plenipotentiary for Aviation, Director of the Defense Industry Department at the Ministry of Development, Regional Policy and Tourism, Advisor to the Rector of the Military University of Technology. Currently working at the Military University of Technology in Warsaw at the Academic Center for Strategic Analysis and as a lecturer at the Warsaw School of Economics in the field of National Security. Vice President of SSLW RP.

Having held managerial positions in the Armed Forces and government structures for many years, he has acquired extensive skills and experience in commanding and managing aviation and the space sector, as well as in shaping the training system and flight safety rules for Polish aviation at all levels of command and control of the Polish Armed Forces.

Current message

Ladies and Gentlemen,

I invite and encourage you to cooperate in the development of the Polish space sector – an area of key importance for national security and technological sovereignty.

Access to independent satellite data is currently one of the pillars of national defense. Poland must build competence in this area as quickly as possible – it is in our national interest. It is necessary to move from discussion to action: to implement projects that will accelerate technological transformation and strengthen our defense industry.

Investments in military satellites, communications systems, missile defense, and space monitoring must be an integral part of the modernization of the Polish Armed Forces. Only a modern, mobile, and flexible army, supported by its own technological infrastructure, will be able to respond effectively to threats and protect the security of the Republic of Poland.

Prof. dr hab. inż. Jan Andrzej Dziuban

Professor Magnus of the Wrocław University of Science and Technology

General professional information

Prof. Dr. Hab. Eng. Jan Andrzej Dziuban was born on May 5, 1951 in Sanok, where he graduated from Primary School No. 2 (1965) as a laureate of the Mathematics Olympiad for Primary Schools (at that time it was the highest level of thematic olympiads in Poland).

In 1969, he graduated from Saint Sophia High School in Sanok, where he passed his secondary school leaving examination with distinction.

In 1969 he began his studies at the Faculty of Electronics of the Wrocław University of Science and Technology, which he graduated in 1974.

his PhD in technical sciences in 1978 for research on the influence of light on the properties of the MOS structure (PWr).

He obtained his habilitation in 2002 for his research on the technology and anodic bonding of micromechanical silicon and silicon-glass structures and their application in MEMS technology. He has been a full professor since 2008. The research was conducted at the Institute of Electron Technology in Warsaw.

Further professional positions and functions at Wrocław University of Science and Technology:

- assistant professor at the Institute of Electron Technology, Faculty of Electronics, Wrocław University of Science and Technology (transformed into the Institute of Microsystem Technology and then into the Faculty of Microsystem Electronics and Photonics, currently the Faculty of Electronics, Photonics and Microsystems) 1978-2007;
- associate professor at the Faculty of Microsystem Electronics and Photonics, Wrocław University of Science and Technology 2007-2010;
- full professor, then professor (2010-2021)
- Professor Magnus of the Wrocław University of Science and Technology (from 2023).

Scientific activities and knowledge commercialization

Head of the Faculty's Micromechanics and Microengineering Laboratory (2006-2009).

Head of the Faculty's Department of Microengineering and Photovoltaics (2009 to 2016).

Vice-Chairman of the University Disciplinary Committee.

Chairman of the Chapter of the Professor Dionizy Smoleński Award.

Currently, he is the head of the Space Research Centre at the Wrocław University of Science and Technology, operating at the Faculty of Electronics, Photonics and Microsystems.

Work outside the Wrocław University of Science and Technology

Employment as a full-time associate professor (2005-2008) and then associate professor (2009-2010) at the Institute of Electron Technology in Warsaw.

From 2004 to 2006 he worked as a research professor (directeur de recherche) at the Institute FEMTO ST of the CNRS in France, and then as a professor at the Universite Franche Comte in Besancon.

In the years 1991-1994 he was delegated by the authorities of the Wrocław University of Science and Technology to the Polish-Austrian company Kowary sp. z o. o., which he saved from bankruptcy, acting as the Rector's representative, president and its liquidator.

He was the president of the management board of Ophta-Lab, a company owned by the Wrocław University of Science and Technology Development Foundation and the State Fund for Disabled Persons.

He was active as a board member of the Lower Silesian Foundation for the Prevention of Blindness.

On behalf of the Solidarity Electoral Action, he served on the Municipal Economy Committee of the Wrocław City Council. He is a founding member of the Polish Society of Sensor Technology, where he served as a board member and then president of the board from 1991.

He is a founding member of the National Committee for Space Technologies of the NOT and vice-president of this committee for scientific affairs.

National and international awards and distinctions: the team award of the Minister of National Education for achievements in work for the industry - 1997; the team award (2nd place) for the best paper of the European Conference of Eurosensors (European International Sensors and Transducer Conference) - 1997 (Warsaw); Team Award for the best series of SEP articles - 1997; Team Award of the IMAPS (International Microelectronics Packaging Society Conference) conference - 1997; Team Award of the ELTE (Electronic Technologies) conference - 1997; Individual Award (3rd place) of the European Eurosensors Conference for the best scientific paper - 1999 (The Netherlands); Team Award for the best Mixdes paper - 2008; Team Award for the best IMAPS paper - 2009; Team Award for the best IVNC paper - 2009 (Japan); Team Award for the best FBMT (Fundamental Bases on Nanomechanochemistry) paper - 2009 (Russia); Team Award (3rd place) for the best presentation of the European Eurosensors Conference 2010 (Austria), Team Award for the (3rd place) for the best presentation at the European Eurosensors Conference 2011 (Greece) (he is the only four-time winner of the Eurosensors award); Team Award at the conferences on micro and nano systems with energy conversion Power MEMS 2016, 2022, IVNC 2017, ELTE 2018.

Jan Dziuban holds numerous distinguished positions in the advancement of scientific research. He was a member of the Eurosensors Conference Steering Committee (from 1994 to 2018, currently on the Honorary Committee). He is a member of the IVNC Micro/Nano Vacuum Electronics Conference Committee (elected every four years since 1999); and a member of the Power MEMS Conference Steering Committee (elected twice since 2018).

He was a member of the Nano and Microtechnology Section of the Committee on Machine Design of the Polish Academy of Sciences, the Microsystems and Sensors Section of the Committee on Metrology and Scientific Equipment, and the Microelectronics Section of the Committee on Electronics and Telecommunications. He was an expert on gas microsystems from Schlumberger (F) (2000-2001); and an expert in the Foresight Polska 2020 Program.

Prof. Jan Dziuban co-organized the Eurosensors XI Conference (1997) in Warsaw; was co-chair of the IVNC conference (1999) in Darmstadt/Wrocław; co-organized the COE (Optical and Electronic Sensors) 1994 and ELTE 2000 conferences; chaired the Organizing Committee of the COE'04 conference in Wrocław; was a member of the Scientific Committees of the COE conferences; and was a member of the Scientific Committees of several global Eurosensors Conferences: the IVMC (and IFES) Conference, the COMS Conference on Commercialization of Microsystems, the NAMIS Conference on Nano and Microsystems, and the Power MEMS Conference. He has frequently served as a reviewer on the awards committees of leading global conferences and congresses such as Eurosensors, Transducer, MicroTotal Analysis, IVNC, and IFES.

He was the chairman of the IVNC 2008 conference (Wrocław), Eurosensors 2012 in Poland, and vice-chair of the COMS 2015, NAMIS 2015, and PowerMEMS 2019 conferences. Particularly noteworthy is the development of the presence of Polish technological thought in the field of analytical microsystems at Achema congresses, where the group led by Professor Dziuban was often the only repeat exhibitor and scientific presenter at this world-class economic and scientific event.

Professor Jan Dziuban has participated in the development and implementation of numerous national and international research projects in the field of microsystems. Among the most important are groundbreaking research projects from the 1990s, focusing on a family of silicon pressure microsensors, culminating in industrial implementation at the TEWA-CEMI plant. These groundbreaking research projects focused on the technological foundations of MEMS and lab-on-chip microsystems, which laid the foundations for Polish technology in such microsystems, used both domestically and internationally for decades to come. Unfortunately, the pseudo-economic reforms of the 1990s devastated the Polish microelectronics industry, and the production of sensors and the development of other MEMS microsystems were thus thwarted. For these reasons, among others, Professor Dziuban focused on international collaboration.

As a Polish scientist, he was invited to participate in two PR6 projects related to the development of fluidic microsystems. This included the NEPUMUC PR6 project (ICT leader Fraunhofer Institute, Germany) – the goal of which was to develop microreactors for the production of explosives (PhD thesis by Dr. Eng. Paweł Knapkiewicz), whose results were then applied in practice. In the PR6 LABCARD PR6 project (Ikerlan leader, Spain), he served as project manager, executing the work carried out in Poland (ITE Warsaw). The project aimed to develop the first European analytical instrument using lab chips for the rapid detection of bacterial pathogens using PCR-DNA. The pioneering results obtained here enabled the development of a family of instruments using polymer lab chips (PR6 Lab-on-Foil project), and then – the culmination of this research line – the development of an instrument for the prenatal detection of pathogenic mutations in human fetuses by examining DNA extracted from the peripheral blood of pregnant women (PR7 Angel-Lab project). The results of this work became a significant contribution to the habilitation of Prof. Dr. hab. Eng. Rafał Walczak.

In 2004, Prof. Dziuban initiated (together with Prof. Ch. Gorecki from FEMTO ST CNRS) the European MAC-TFC project (PR7 leader CNRS FEMTO ST France, 2008-2012). In this project, carried out with the participation of the Faculty of Electronics, Photonics and Microsystems of the Wrocław University of Science and Technology, he led the development of MEMS optical microcells for the CSAC (Chip-Scale Atomoc Clock) cesium atomic microclock utilizing the CPT (Coherent Phase Trapping) effect. This long-term research effort led to the creation of such a clock (prototyped in the PhD thesis of Dr. Piotr Dziuban), and the so-called laser dispensing technology, "refined" at Wrocław University of Science and Technology (2008-2016), crucial for the production of cesium optical MEMS for atomic microclocks, is now used by research and production centers around the world. The lack of proper relations between research and industry centers in the so-called Old European Union prevented the production implementation of the European atomic microclock developed in the MAC-TFC project, a fact regretted almost 20 years after the project's inception at the European Commission. It would be great if such a topic were taken up again in Poland.

Another project initiated by Professor Dziuban was the concept of portable, suitcase-based, autonomous lab-on-chip analytical instruments for detecting biological attacks on the battlefield and in response to terrorist threats. This concept was implemented in the SFORA defense project, where Professor Dziuban served as the principal investigator, project coordinator, and co-executor of the research and development work. The research yielded, among other things, a super-highly sensitive DNA capillary electrophoresis method enabling the identification of a single DNA mutation (PhD thesis of Dr. Eng. Wojciech Kubicki). The successfully completed project received the DEFENDER award (2014), but Polish military officials squandered this achievement, even though it could have solved the problem of mass PCR-DNA testing during the COVID-19 epidemic and remains important in identifying various bacterial and viral infections in wild and farm animals, ignoring the bio-military aspects.

Professor Dziuban initiated and coordinated the ERA-NET project, the aim of which was to develop (in collaboration with CNRS LAAS in Toulouse, France) a MEMS microdosimeter for measuring high doses of ionizing radiation, above 10 MGrey, which is crucial in nuclear power plant failures, nuclear attacks, and the construction of next-generation nuclear stacks. Such a sensor was developed (PhD thesis by Dr. Izabela Augustyniak).

Professor Dziuban initiated and scientifically coordinated an industrial project, the so-called NCBiR Fast Track, on a "smart" home gas meter (a project for the ELEKTROMETAL company in Cieszyn), suitable for metrological assessment of the quality of supplied natural gas. Work on implementing this solution continues.

Meanwhile, Prof. Dziuban initiated research on a lab-chip instrument for metrological assessment of the biological potential of oocytes and embryos from farm animals, with the aim of supporting embryo transfer, an important technique for enhancing the quality of breeding stock. In the APOZAR POIG project, initiated by Prof. Dziuban, an innovative instrument and the so-called quality field method were developed, enabling material classification based on VIS/NIR absorbance spectra (PhD thesis by Patrycja Śniadek, PhD). Simultaneously, he developed research on a family of lab-chip instruments for conducting micro-scale biomedical experiments with a variety of biological signal detection techniques (PhD thesis by Agnieszka Krakos, PhD).

In 2015, Professor Dziuban delivered an invited talk at the Fly Me to Mars conference in Wrocław, presenting his vision for the development of analytical microsystems for space applications. The thesis was positively received by, among others, the Jagiellonian Club, but went unnoticed in the space sector.

In 2017, Professor Dziuban became involved in the development of the Lower Silesia Development Strategy (2017). His initiative, along with that of Professor Anna Chełmońska-Soyta from the Wrocław University of Environmental and Life Sciences, included microgravity biomedicine. He established collaboration with three research centers in Wrocław (the Wrocław University of Environmental and Life Sciences, the Institute of Immunology and Experimental Therapy of the Polish Academy of Sciences, and the Medical Academy), as well as with SatRevolution. This resulted in the establishment of a scientific-industrial project focused on developing the first nanosatellite, biomedical mini-space laboratory, including a space test at the Lower Silesian University of Environmental and Life Sciences. This project was accepted by the National Centre for Research and Development. Professor Dziuban serves as the principal investigator and research investigator. The specific goal of the project was to conduct selected cytometric studies in an automated subminiature chip laboratory (the first solutions for such a laboratory were developed by the team led by Prof. Dziuban at the Wrocław University of Science and Technology), which serves as the payload for the Lab-Sat 3U nanosatellite. This project was successfully completed; in January 2022, the laboratory was launched into orbit, where proper operation of the equipment was confirmed, and the first European biological experiment in orbit using nanosatellite technology was conducted (PhD thesis by Dr. Adriana Graja). Based on these solutions, an ESA project is currently underway to build a portable, suitcase-based space instrument for peri-oncological research on board the ISS. Work is also underway on the concept and implementation of a lab-chip instrument set for the 2028 satellite mission, prepared jointly with Taiwan.

Meanwhile, Professor Dziuban and his team began work on a family of MEMS ion-atomic microspectrometers in collaboration with the National University of Singapore (NUS), under Polish-Singapore funding for a project under the NCBiR-A*STAR link. This solution, with its globally innovative features, was recognized by ESA. The team's efforts, initiated by Professor Dziuban, to secure an ESA project to improve the spectrometer and produce a version capable of analyzing ion masses and charges were successful. The result is a subminiature ion mass spectrometer with features suitable for space applications. Currently, work is underway on a MEMS ion mass spectrometer to study the thermosphere at LOE from 500 to approximately 1000 km for a Polish weather satellite (leader Creotech, Warsaw) as part of the Space Weather project financed by ESA.

In parallel, Prof. Dziuban initiated and coordinated work on a highly sensitive MEMS ion microspectrometer for the analysis of biotic methane on Mars, in collaboration with JPL (Jet Propulsion Laboratory) . Models of such instruments have been obtained that meet the application assumptions, but the project's future is uncertain due to significant restrictions recently introduced on JPL's collaboration with non-American centers.

A team led by Professor Dziuban developed a concept for a MEMS instrument to analyze sulfur aerosols for the Venusian mission undertaken by MIT (Professor Sara Seager). Internal US policy considerations resulted in the interruption of MIT's work on this mission.

The concept of autonomous instruments for the future Artemis III and IV lunar missions is being developed. It is planned to build an autonomous small lunar vehicle with three MEMS analyzers of gas and solid composition (a laser ablation ion spectrometer, a mass spectrometer, and an X-ray analyzer). This work will be carried out jointly with the Space Research Centre of the Polish Academy of Sciences in Warsaw (CBK PAN) and, possibly, with international teams.

Professor Dziuban co-authored the concept for a Polish nanosatellite mission to Mars and was one of the founding members of a consortium composed of leading Polish universities and representatives of the Polish and American space sectors (formerly Virgin Orbit and JPL). Advanced work on the mission was interrupted by the COVID-19 pandemic. This is a shame, because such a space "target" would have been an integrator and a driving force for the development of the Polish space sector and Polish-American co-operation, which requires a significant shift in political and economic direction in Poland.

Professor Dziuban is the author of numerous scientific papers (over 500 articles, approximately 1200 citations), holds several patents, is the author of an internationally recognized book on the role of bonding in microsystem technology (Bonding in microsystem technology , Springer) and co-author of several books in the field. He has supervised many master's and doctoral students, some of whom have achieved independent scientific activity and professorships.

He's a passionate yachtsman, motorboater, and boatbuilder. He restores vintage cars and motorcycles. And when he's bored in the winter, he builds scale models of airplanes and boats.

In summary, Professor Jan Andrzej Dziuban is largely a founder of microsystems technology, making significant national and international contributions to the development of integrated sensors, micro- and nano--MEMS technologies, and pioneering work in frontier dual-use technologies, both on Earth and in space. To illustrate the above, several tables summarize the most important facts from Professor Dziuban's professional life.

In the Professor's opinion, many years were wasted by Jaruzelski's regime and the struggle to address the consequences of the so-called Balcerowicz reforms of the 1990s. Those years cannot be reversed. Where would Poland be if history had been kinder to all of us?

Table 1. **Selected awards and distinctions**
1997 Award of the Minister of National Education for achievements in work for the benefit of industry
1997, 1999, 2010, 2011 (Warsaw, Twente, Athens, Linz) 4 awards for the best paper of the European Conference on Eurosensors (European International Conference on Sensors and Transducers) (JA Dziuban is the only four-time winner of this conference)
1997, Team Award for the best series of articles in the publications of the Association of Polish Electrical Engineers SEP
1997, 2009 2 Awards of the IMAPS Conference Team (Intern. Conf. of Microelectronics Assembly and Packaging Society); **ELTE Conference Team Award** - 1997;
2008, 2010 2 Team Awards for the best paper of the Mixdes conference (International Conference on Mixed Design and Integrated Circuits and Systems)
2009, 2017 (Osaka, Freiburg) 4 team awards for the best papers of the IVNC conference (International Vacuum Nanoelectronics Conference {JA Dziuban is the only four-time winner of IVNC awards)
2016 **, 2019, 2022 (Paris, Krakow, Salt Lake City) 3 Power MEMS Conference Team Awards** (International Conference on Micro and Nanotechnology for Power Generation, Conversion and Application)
2017 Award of the Patent Office of the Republic of Poland 2017
2018 and 2019 ELTE and COE Conference Awards, Paris 2022 Astronautical Congress Award
Winner of the DEFENDER award at the XXI International Defence Industry Exhibition

Table 2. **Achievements**

- Development **of a gas microchromatograph** (together with EMAG Katowice, financed by the State Committee for Scientific Research)
- Development of microreactors **for nitration of hydrocarbons** (PR6, together with Fraunhofer Institut ICT, Germany)
- Development of **European DNA rtPCR instruments** for the detection of food pathogens (FP6, jointly with IKERLAN, Spain)
- Development of **a European MEMS atomic microclock with CPT effect** (PR7, jointly with Universite Franche Comte and FEMTO ST France)
- Development of **a set of portable genetic laboratories** for detecting **biological attacks** (NCBiR together with MIHiE Warszawa/Puławy)
- Development of **a MEMS mass spectrometer** for detecting industrial contamination (NCBiR/A*STAR Singapore)
- Development of **a bio/medical lab-chip for nanosatellites** with a methodology for use (NCBiR, jointly with SatRev Wrocław)
- Development **of a MEMS plasma spectrometer** to detect **methane on Mars** (with JPL NASA, Caltech CA USA)
- Development of **a MEMS ion mass spectrometer** for space applications (ESA project)

Table 3. **Projects**

- **1988-1992, 1994-1998** MEMS family of pressure sensors, accelerometers (TEWA-CEMI)
- **1996-2004** micro gas chromatograph for detecting explosive atmospheres in hard coal mines (CEMAG/ITE) TRL 6, used
- **1998-2004** Two fundamental projects on the foundations of MEMS technology
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- **2019-2022** Polish lab-sat project CubeSat TRL9 (space test)
- **2019** - PL/USA (JPL Caltech) project " *Plasma MEMS biotic methane detector at Mars"* suspended
- **2022-2024** ESA project " *MEMS untegrated space miniature ion mass spectrometer"*
- **2024**- ESA project " *Space Weather Satellite* "

The space sector in the state defense and security system. Strategic analysis and recommendations for action

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Introduction

In the era of network-centric warfare and hybrid conflicts, space has been recognized by NATO as the fifth operational domain—alongside land, sea, air, and cyberspace. This study presents the strategic importance of satellite technologies for modern defense systems and the national security of the Republic of Poland, embedding the analysis in the context of the global transformation of the battlefield, where information is becoming a decisive factor of advantage.

Despite the adoption of the Polish Space Strategy in 2017, which envisages building a national space potential by 2030, key implementing instruments—the National Space Program and the Space Activities Act—have not yet been developed and implemented. The Ministry of Development and Technology has failed to prepare the required legal acts, create mechanisms for monitoring the implementation of the National Space Program, and ensure proportionality between Poland's contributions to ESA and the value of contracts awarded. As a result, the participation of domestic companies in ESA tenders is among the lowest in Europe. A lack of coordination between the Ministry of Energy, Technology, and the Ministry of National Defense (MAP) is also problematic. This results in the dispersion of resources, duplication of expertise, and a loss of synergy between the civilian and defense sectors.

Therefore, it is recommended to establish an inter-ministerial space policy coordination center with clearly defined competencies, a budget, and performance metrics. It is also essential to develop a defense industry development strategy that integrates cyber and satellite components. This requires strengthening international cooperation, particularly within NATO in the areas of Space Domain Awareness (SDA) and Space Situational Awareness (SSA), and actively involving Poland in the development of the European Defense Technological and Industrial Base (EDTIB), in line with the assumptions of the European Defense Industry Strategy.

Satellite technologies are the foundation of modern defense—they determine the effectiveness of command, crisis response, and early warning systems. Investments in national space capabilities should therefore be treated not as an element of industrial policy, but as an investment in national security and sovereignty. Without a fundamental reform of the space sector's governance system, Poland will not be able to ensure its security in the 21st century.

The use of space determines the outcome of armed conflicts, where advantage is gained not by the number of tanks or missiles, but by the ability to rapidly process and transmit information. For this reason, highly developed countries treat space as a strategic environment for competition. Its importance is evidenced by NATO's decision in November 2019 to designate space as the fifth operational domain.

In the face of current geopolitical tensions and the climate crisis, there is a growing demand for space technologies that enable rapid threat detection, crisis impact assessment, and preventive action planning. Space is becoming the foundation of modern defense – an integral part of combat operations and a guarantee of security in peacetime.

There are approximately 13,000 satellites in orbit. The decreasing cost of launching such payloads has led to nearly one hundred countries operating their own satellites. Poland has two owned by the Space Research Centre of the Polish Academy of Sciences, the rest by private companies. The global space market is estimated at €450 billion. Its annual growth rate is 15-20 percent, and by 2040, the sector could reach $1.8 trillion, making it one of the fastest-growing sectors of the global economy. The Polish space market is worth over $2 billion and includes 300-400 companies and research institutions, employing 12,000 people. Polish companies have already developed over one hundred space technologies, and their potential will grow with greater participation in EU and European Space Agency (ESA) programs. Thus, the next stage of the industrial revolution is unfolding before our eyes.

However, existing state support mechanisms for the defense industry, including the space industry, have proven insufficient. The lack of a clear division of responsibilities, duplication of structures, complex procedures, and blurred accountability undermine the system's efficiency and, consequently, the country's defense. The generation gap, low workplace identification, and lack of institutional continuity intensify the need for deregulatory changes.

To meet global challenges, systemic solutions must be implemented. The Polish space sector remains weak due to its lack of a coherent strategy, centralized decision-making, and consistent operations. The Polish Armed Forces should develop a strategy that takes into account the operational space domain, and the Ministry of Development and Technology – in conjunction with the Ministry of National Defense and the Ministry of National Defence – should prepare a defense industry development strategy. Decisions regarding the space sector should be centralized in a single institution with full financial resources for such projects, both civilian and military.

The government's priority, especially in light of Poland's frontline position and the ongoing war in Ukraine, should be to increase defense readiness by leveraging domestic industrial potential. A strong and competitive defense industry, including the space industry— which provides the Polish Armed Forces with access to modern communications and weaponry—is a key element of national security.

The most important government body responsible for defining and implementing Polish space policy is the Ministry of Development and Technology (MRiT). Its responsibilities include shaping and implementing space policy. Within the MRiT, space policy-related tasks were previously handled by the Department of Innovation and Industrial Policy, but since December 2025, they have been taken over by the Department of Defense Industry, responsible for supporting the development of the national defense industry, including the space sector. The Department exercises substantive oversight of the Polish Space Agency (POLSA), handling matters arising from Poland's membership in ESA and concerning the space policy of the EU and the Republic of Poland. The Department supports POLSA in carrying out these tasks, which has been subordinate to the Minister of Development and Technology since July 20, 2019.

A number of other state entities are also involved in the implementation of the Polish Space Strategy, operating both at the strategic level – in the area of planning and coordinating space policy – and at the operational level, including implementing programs, conducting research and supporting industry.

Institutional system of the space sector in Poland

There is currently no single coordinating body with real decision-making authority regarding the space sector. Poland has an extensive system of institutions involved in space activities. This means that responsibilities regarding space matters are dispersed across state institutions. The most important of these are outlined below.

- Ministry of Development and Technology (MRiT): Coordination of the state's space policy and, among others, substantive supervision over POLSA, Poland's representation in ESA and on the EU forum, responsibility for the National Space Program, and the Act on Space Activities
- Ministry of National Defence (MON): including defining operational needs in the field of satellite observation, communication and navigation systems, implementing space security projects (e.g. the National Satellite Information System), cooperation with the European Defence Agency (EDA) and the NATO Space Centre, coordination of the military segment of the Copernicus programme
- Ministry of State Assets (MAP): including supervision over state-owned companies implementing space and defense projects (e.g. Creotech Instruments, PIAP Space, PIT-RADWAR, PGZ), investment and consolidation policy in the area of dual-use technologies
- Ministry of Digital Affairs: including participation in the Galileo system, including responsibility for the national PRS (Public Regulated Service) segment, supervision of the national GNSS (Global Navigation Satellite System) infrastructure, cooperation within the GovSatCom program (secure government communications)
- Ministry of Climate and Environment: including Poland's representation in the EU-METSAT organization (meteorological satellites), the use of satellite data in environmental, climate and agricultural policy
- Ministry of the Interior and Administration (MSWiA): Including the use of satellite systems in internal security, rescue and crisis management, coordination of access to the PRS signal
- Ministry of Foreign Affairs (MFA): including international cooperation in the area of space law and technological diplomacy, Poland's representation in the UN COPUOS (Committee on the Peaceful Uses of Outer Space), support for international negotiations on the registration and liability for space objects
- Ministry of Science (MNiSW / formerly MNiSzW): including financing of scientific research in the field of space technologies, cooperation with the National Centre for Research and Development, the National Science

Centre and institutes of the Polish Academy of Sciences, coordination of participation in the Copernicus programme and ESA research projects
- Ministry of Finance (MF): including financing of Poland's participation in ESA and EU programs, settlement of membership fees, supervision of technology transfers and export controls (jointly with the Ministry of National Defense)
- Ministry of Infrastructure: responsible for, among others, satellite transport, ground infrastructure (receiving stations, communications) and the integration of space systems with the transport infrastructure
- National Security Bureau (BBN): including assessment of the strategic importance of space technologies for national security, cooperation with the Ministry of National Defense and the Ministry of Energy and Technology on defense projects (e.g. in the field of observation and communication satellites).

Government institutions and agencies:
- Polish Space Agency (POLSA) – key executive institution (coordination of national space policy, register of space objects, advice to the government, international cooperation)
- Civil Aviation Authority (ULC) – licensing and safety issues for launching objects and near-space airspace
- Head Office of Geodesy and Cartography (GUGiK) – use of satellite data in Earth observation and geolocation systems
- Central Statistical Office (GUS) – collecting data on the activities of the space sector in Poland.

Advisory bodies and coordination teams:
- Inter-ministerial Team for Space
- Parliamentary Group for Space.

Key scientific and research institutions:
- Space Research Centre of the Polish Academy of Sciences (CBK PAN) – a research center in the field of space technologies and instruments, participating in ESA and NASA missions
- Nicolaus Copernicus Astronomical Center of the Polish Academy of Sciences – research in the field of astrophysics, observational astronomy, and cosmic theory
- Committee for Space and Satellite Research of the Polish Academy of Sciences – an advisory body of the Polish Academy of Sciences in the field of space sciences and international cooperation
- National Centre for Research and Development (NCBR) – finances research and development projects in the field of space technologies and supports cooperation between science and industry.
- Polish Agency for Enterprise Development (PARP) – supports the development of innovative enterprises operating in the space industry.
- Institute of Aviation – Łukasiewicz Research Network (active in ESA projects, e.g. PW-Sat satellites, EagleEye).
- The Institute of Geophysics of the Polish Academy of Sciences, the Institute of Low Temperatures of the Polish Academy of Sciences, the Institute of Nuclear Physics of the Polish Academy of Sciences – conduct research as part of ESA and NASA projects.
- Nicolaus Copernicus University Astronomical Centre in Toruń – participates in radio telescope and observation projects.
- Institute of Geophysics of the Polish Academy of Sciences, Institute of Low Temperatures of the Polish Academy of Sciences, Institute of Nuclear Physics of the Polish Academy of Sciences – participation in ESA and NASA scientific projects.
- Nicolaus Copernicus University Astronomical Centre (Toruń) – participation in radio telescope and observation projects.

Academic centers conducting research and education in the field of space engineering:
- Military University of Technology (WAT)
- AGH University of Science and Technology (AGH)
- Warsaw University of Technology (WUT)
- Wrocław University of Science and Technology (WUT)
- Gdańsk University of Technology (PG)
- Lodz University of Technology (TUL)
- Rzeszów University of Technology
- University of Zielona Góra
- Wrocław University of Environmental and Life Sciences

Industry organizations and networks:
- Association of Space Sector Employers (ZPSK)
- Space and Satellite Engineering Cluster at the Military University of Technology (WAT)
- Polish Space Technology Platform
- National Committee for Space Technologies (SITK/NOT)

Satellite technologies in the defense system of the republic of Poland

Satellite technologies play a key role in the areas of reconnaissance, communications and missile defense systems.

In terms of reconnaissance, they enable real-time intelligence gathering, enabling, among other things, monitoring troop movements, detecting military installations, and analyzing changes in enemy infrastructure. Modern observation satellites offer high-resolution imagery and the ability to operate in diverse weather conditions.

In the area of communications, satellites provide stable, secure connections between military units deployed in different parts of the world. They guarantee transmission independent of terrestrial infrastructure, which is crucial for military operations conducted in difficult terrain.

In missile defense, satellites act as early warning systems against missile attacks. An example is the American SBIRS (Space-Based Infrared System), which detects ballistic missile launches, tracks their trajectory, and transmits data to missile defense systems, enabling their coordination.

Conclusions and recommendations regarding the priorities of the development of satellite technologies in the republic of Poland

In the area of satellite observation and communications, Poland remains largely dependent on external entities. The Polish Armed Forces alone spend more than PLN 100 million annually on Earth observation and satellite communications (this amount does not include the costs of leasing satellite spectrum and equipment).

Poland should develop its own high-resolution observation satellites – both optical (for imaging in visible light) and radar, enabling observations regardless of weather conditions. Synthetic radar (SAR) capabilities will enable effective tracking of military movements, detection of infrastructure changes, and monitoring of large areas.

To effectively utilize space for defense purposes, Poland should develop its own technologies in the areas of reconnaissance and communications satellites, missile defense systems, and space monitoring, while simultaneously deepening cooperation within NATO and the EU. Active participation in international projects that provide access to the latest technologies and systems is also crucial. The focus should be on satellites that meet both civilian and military needs.

In May 2024, Prime Minister Donald Tusk announced the approval of a €300 million loan for the development of the Polish satellite component of the European Missile Defense Shield program. These funds could not only provide an impetus but also a real lever for the development of the domestic space industry. However, participation in the European Missile Defense Shield initiative is not an alternative to Polish defense programs, but a significant complement.

Acquiring and developing capabilities to observe and track space objects are crucial for the Polish Armed Forces due to:

- the growing activity of states in space, including the launch of objects of unknown purpose,
- the need to plan missions to launch our own satellites, especially in connection with the construction of a national optoelectronic Earth observation system,
- the need to maintain situational awareness of objects entering the Earth's atmosphere in an uncontrolled manner.

The Polish Armed Forces must have the capability to detect and track threats in airspace and space. This requires satellites equipped with infrared detectors and radar systems, enabling space monitoring and ballistic missile detection. These technologies form the basis of early warning and missile defense systems.

Collaboration with countries developing SSA technologies and possessing advanced space monitoring systems and experience in missile defense systems, such as the United States (SBIRS program), is crucial. Collaboration with NATO allies developing similar capabilities is also crucial. Collaboration with space monitoring companies, such as Lockheed Martin and Northrop Grumman, is also essential.

It is also important to deepen cooperation with European partners – France (observation satellite programs), Italy (COSMO-SkyMed), and Germany (radar systems). A good example of cooperation with European partners is Poland's participation in the Copernicus and Galileo programs, which support Earth observation and satellite navigation.

Poland should invest in space monitoring technologies, including developing its own satellites for early detection of space threats, space debris surveillance, collision risk management, and satellite infrastructure protection. Such solutions will enhance national security by protecting both military and civilian systems.

Priority recommendations for the polish defense industry

Effective transformation of the Polish defense industry requires a coherent development strategy integrating military, economic, and political aspects, based on sustainable international cooperation and leveraging domestic technological potential. Achieving these goals should include:

- Linking modernization with international military-economic cooperation (EU, USA, South Korea), taking into account both the country's economic capabilities and defense needs over the next few decades.
- Ensuring a network-centric command and control system, enabling the performance of tasks in the national and allied systems.
- The purchase and operation of weapons should guarantee their unification and be linked to the right to modernization, servicing and development of the domestic defense industry.
- Building a political, economic, and social consensus based on substantive debate and understanding between the Armed Forces, the ruling elite, and the opposition. This consensus should be reinforced by appropriate legal regulations.
- Strengthening national indu-

strial and institutional structures, including the Polish Armaments Group, the Armaments Agency, and the International Defense Industry Exhibition (MSPO). Acquiring and transferring the latest technologies to the Polish defense industry is also crucial.

- Stabilization of structures and modernization plans and the selection of competent leaders capable of effectively managing the transformation.

The post-Soviet combat equipment still present in the Polish Armed Forces is ill-suited to modern threats, and the domestic arms industry has limited modernization capabilities. Therefore, consistency in implementing these actions is essential. The Polish Armed Forces possess a solid base and human potential, built over years, and their development should be non-partisan. This requires the introduction of stable, long-term legal solutions to ensure the continuity of the country's defense policy.

The world is in an intense race to develop space technologies and explore space, which is becoming a key element of technological, economic, and military competition between nations. By 2024, the global space economy had already reached $546 billion, and forecasts indicate that its revenues will exceed $1 trillion by 2030.

Currently, the United States and China are competing for the top spot in this sector's technology, but rivalry also rages between Russia, Japan, and India. A key area of exploration is the exploration of the Moon and Mars, where helium-3 and rare-earth metals, crucial for modern energy and electronic technologies, are located. Countries with developed research and development potential and the ability to launch objects into space gain a strategic advantage. The ability to design and manufacture satellites, launch vehicles, and Earth observation systems is a key determinant of technological power.

Much of the contemporary space sector remains closely linked to the military, embracing dual-use technologies. Major military powers also possess ASAT (Anti-Satellite Weapons) ballistic missiles, which can carry nuclear payloads and destroy objects in space, including enemy satellites. The ability to neutralize space infrastructure is becoming one of the pillars of strategic deterrence. Superiority in space directly translates into military advantage, enabling more effective reconnaissance, communications, and precision targeting. We are currently witnessing the next phase of the technological revolution, of which the militarization of space is a crucial element.

On June 9, 2025, the NATO Secretary General called on member states to quadruple their air defence spending, emphasizing that space capabilities, missile and satellite defence systems are a key element of the Alliance's modern security architecture.

Directions of transformation of the world's armed forces

History shows that those who rely on systems proven in past conflicts will not succeed in future wars. Those who prepare for a war that has already occurred are doomed to failure. The examples of France, Egypt, Iran, Armenia, and most recently, Russia demonstrate that outdated doctrines and equipment, even if impressive on paper, cannot provide an advantage in a modern combat environment.

True military and technological sovereignty requires developing our own capabilities, not becoming dependent on imports. As French President Emmanuel Macron noted during the 2022 arms fair in Paris, "spending a lot of money to buy elsewhere is not a good idea." As early as 1991, Professor Paweł Bożyk, in his book "The Road to Nowhere," wrote that a country that buys weapons is a backward country. Michèle Flournoy, former US Deputy Secretary of Defense, briefly summarized the current trends in armed forces modernization during her testimony before Congress: "megabits instead of megatons." The future belongs to digital technologies, autonomous and unmanned systems capable of interoperating with satellites, piloted aircraft, manned ships, and artificial intelligence.

Flournoy identified three pillars of a modern armed forces:

A network-centric command and control system—connecting all elements of the battlefield into a single, coherent information network. The idea of "connecting everything to everything" is already being implemented in the United States, which has made its own armed forces a testing ground for this type of solution.

Autonomous systems cooperating with humans – implemented in all branches of the armed forces on an increasingly large scale.

Artificial intelligence – the key to analyzing data, which has become one of the main battlefields today.

Contemporary defense discussions are increasingly less concerned with individual platforms—tanks, aircraft, missiles, or even satellites. The focus is shifting to integrated networks, communications, data, and the potential of AI technologies that automate decision-making, predict events, assess risks, and support operations. It's worth emphasizing, however, that no modern battlefield asset, even the most advanced one, is significant unless it's connected to a disruption-resistant, secure, and high-capacity IT network. It's this network—not a single weapon system—that determines military advantage in the 21st century.

General principles of the process of building the polish space sector

Strategic aspects

- The process of building the Polish space sector should be determined by international military and economic cooperation, while taking into account national technological and financial capabilities and defense needs over the next few decades.

- However, excessive dependence on foreign partners should be avoided – a cooperation model in which Polish entities act solely as subcontractors leads to a loss of technological independence and the outflow of specialists abroad.
- Poland should maintain the ability to operate in parallel within the national and allied systems, while striving for equipment unification and interoperability.
- Defense and technological aspects
- National defense and security needs should be met through the use of the latest available satellite technologies.
- The operation of equipment should be combined with the right to its servicing, modernization and further development, which strengthens the competences of the domestic industry.
- It is a mistake to focus on one technology – several domains should be developed in parallel, including space technologies, network-centric command systems and autonomous means of action.
- It is necessary to promote the development of new space technologies and raise public awareness of the importance of space as a new operational domain.
- Institutional and organizational directions
- It is necessary to establish a coherent organizational structure to coordinate national space activities.
- Space activities should be treated as a tool for supporting innovation, economic development and improving the efficiency of state institutions.
- Cooperation between public administration, science and industry is of key importance, as is increasing the innovation and competitiveness of enterprises through the development of satellite and space technologies.
- Stable financing and increased spending on space research, treated as a strategic investment, are required.

Social and educational aspects

- It is necessary to ensure a broad political, economic and social consensus around the development of the space sector.
- What is needed is a substantive public debate and a lasting understanding between the armed forces, the ruling elites and the opposition – preferably in the form of a legally binding commitment.
- A system for identifying and supporting talents in the field of space technologies should be created – Poland has the potential to become a leader in this area, but currently it is too weak in this direction.

The overarching goal of Polish space policy should be achieving autonomy across the full scope of space exploration. The ability to independently design, build, and manage satellites provides not only greater security but also real influence over national interests in the new global geopolitical order. The lack of strategic planning, the fragmented structure of the Polish space sector, and its management methods prevent real success. Strong organizational, task-oriented, and financial support from the state is required.

Comprehensive consideration of the presented solutions will ensure the restoration of strategic continuity and a return to a state-based strategic approach to defense and national security, including the crucial role and place of the Polish space sector. Greater focus should be placed on achieving autonomous capabilities, production readiness, and national capacity to meet needs.

Given the difficult geopolitical situation, with Poland threatened by aggression from Russia, a separate ministry should be established to encompass the entire country's military potential. Consolidation of management and leadership efforts is essential. This ministry's policy, developed in cooperation with the Ministry of Energy and Technology, the Ministry of National Defense, the National Defense Ministry, and other ministries based on the national security strategy and the Political-Strategic Defense Directive (currently outdated), would determine requirements for industry regarding innovation, its implementation, and production. Public and private companies should cooperate. The General Staff of the Polish Army, which develops plans for the development of the Polish Armed Forces, should be the driving force behind solutions serving the military. Based on this, industry should refine programs to meet specific requirements.

The Armed Forces should define needs. Projects and industrial capabilities should be compatible with long-term programs and plans for the development of the Armed Forces.

The promotion of the Polish defense industry should also change. Currently, it is highly fragmented and divided among numerous institutions, for which no one takes responsibility. Promotion should be managed by the state through a newly established ministry.

The new proposed system will ensure there's no competition for who's more important – this transcends divisions. Ensuring national security is paramount. Therefore, crucial decisions should be made at the national level, not at the ministry level. ◀

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A new decade of Polish presence in space

Grzegorz Wrochna

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At the Polish Space Agency (POLSA), we have always enthusiastically entered the new decade with ambitious development plans to strengthen Poland's position on the international stage and accelerate technological and economic progress in the country. In an era of increasing competition in the space sector, as a key institution, we have worked with commitment to build space infrastructure, develop innovative technologies and promote international cooperation. Our priorities for the coming years, in my opinion, should include, among other things, the development of advanced satellite systems, participation in space exploration, enhancing security in orbit, and building a human resource base for the space sector.

The Polish Space Agency (POLSA) was established in 2014 to support the development of the domestic space sector and integrate it with international programs. Over the decade, Poland has become an active participant in global initiatives, signing agreements with ESA, NASA and agencies from France, Italy, the US and Israel, among others, and joining the Artemis Accords in 2021 opened the way for Poland to participate in lunar exploration missions.

So far, the effect of the Polish Space Agency's activities has been the dynamic development of the space industry in Poland, which now numbers more than 400 entities, including companies, research institutes and universities. More than 150 of them are directly involved in European Space Agency (ESA) projects, with contracts worth more than €140 million. Total employment in the country's space sector is estimated at nearly 12,000 full-time jobs within several hundred business entities, compared to only 331 in 2020.

POLSA also actively participates in international projects on space security, orbital robotics and satellite communications. It cooperates with ESA within the framework of the Space Situational Awareness (SSA) program, monitoring space around the Earth, and participates in projects such as ENTRUSTED, which supports the development of secure satellite communications for government, and PERASPERA, focusing on space robotics. In the coming years, intensive development of satellite missions and the space security system can be anticipated and a significant share of the European space market can be achieved.

Satellite systems: a pillar of Poland's technological inde pendence

In recent years, we have been working intensively on one of the key projects - the expansion of the National Satellite Information System (NSIS), which should become the foundation of modern satellite data management in Poland, fulfilling several important functions. First of all, it will enable us to monitor environmental changes and analyze natural resources, which we consider essential in the context of energy transition and sustainable development. In addition, NSIS will play a key role in emergency management, providing precise data on natural disasters such as fires, floods and atmospheric phenomena, which will significantly improve the effectiveness of our emergency response.

As part of the expansion, more than 70 new satellites can be launched, which will be used for Earth observation, navigation and communications. These satellites will play a key role in the realization of national technological goals, such as the development of geospatial services, monitoring of agricultural land or support for the defense sector. The development of satellite systems will help strengthen Poland's independence in acquiring data, which can be considered extremely important in the context of global challenges related to natural resource management and environmental protection.

Astronaut on the ISS: a landmark moment for Poland

The year 2025 is already a landmark year for the Polish space sector - as early as this spring, a Polish astronaut, Slawosz Uznański-Wisniewski, was fly to the International Space Station (ISS) as part of the Ignis mission. This mission not only symbolizes the technological progress and advancement of the Polish space industry, but also provides a unique opportunity to carry out numerous scientific studies. It is scheduled to carry out several experiments covering such fields as biology, physics, medicine and materials engineering. The results of this research are applicable not only in the space industry, but also on Earth, including regenerative medicine and the development of new materials.

Our preparations for the mission to the ISS were comprehensive and included both close cooperation with international agencies such as the European Space Agency ESA and the American NASA, as well as intensive educational and promotional activities. We were committed to organizing numerous workshops, lectures and educational events to introduce young people to space exploration. We are also pleased to see how such initiatives not only build public awareness, but also inspire the younger generation to choose a career in the space sector.

Exploration of the Moon and Mars: global ambitions

POLSA has also been actively involved in international initiatives on lunar and

Mars exploration. One of these is the Artemis Program, which aims to establish a permanent base on the Moon and test the technologies needed for further exploration. The program opens up a number of opportunities for cooperation on a global scale. As a signatory to the Artemis Accords, it is with great hope that we are building relationships with leaders in space exploration, and in turn building opportunities to contribute to the development of key technologies.

The role of Polish companies and research institutions in these projects, among others, will be to provide advanced research instruments, data analysis software and robotic systems. It is gratifying to see how Polish companies involved in the development of space technology are participating in projects related to the construction of infrastructure on the Moon, which has gained importance in recent years due to the growing interest in this celestial body. Participation in exploration projects on Mars, too, is a key step in the search for life on other planets, with the intention of testing technologies to enable future manned missions.

Space security as a priority

With the growing number of satellites in orbit, ensuring safety in space should be one of the key priorities. Together with the EUSST consortium, POLSA has been working on systems for monitoring space traffic and warning of potential collisions. Our POLON System, a tool for analyzing data and tracking active satellites and space debris, will allow us to better manage on-orbit traffic and hail alerts on impending threats. Space security is crucial for future exploration and commercial missions, and the development of collision avoidance and space debris management technologies is becoming a sine qua non for the long-term use of space. By engaging in these projects, Poland can play an important role in global efforts to protect space resources.

Education: an investment in the future

At the Polish Space Agency, we have for years considered the development of education and the inspiration of young people to be a key part of our activities. That's why we have been so enthusiastic about programs such as the Al Worden 'Endeavour' Scholarship, which offer young people and students the opportunity to gain practical skills and participate in international projects. Thanks to these initiatives, young Poles have the chance to work on new technologies, develop their competencies in the rapidly growing space sector and gain experience that will be invaluable on the job market.

We have also organized various educational events, such as hackathons, student competitions and technology workshops. Our initiatives promote creativity and innovation, encouraging young people to challenge themselves in areas such as engineering, programming or data analysis. We are pleased to see how hackathons, such as NASA Space Apps and the CASSINI Hackathon, engage participants in finding solutions to real-world problems, enabling young people to gain experience and develop practical skills.

Strengthening cooperation with ESA

We have worked intensively to strengthen cooperation with the European Space Agency, which we consider crucial to the development of the Polish space sector. We have proudly implemented trainee programs, such as the Polish National Trainee Program, which give young Poles a chance to gain valuable experience in an international organization, as well as enable them to cooperate with leading research institutions. In our opinion, such cooperation contributes to the effective transfer of knowledge and technology, which is essential in the context of innovation and competitiveness of the space sector.

At POLSA, we have also sought to actively participate in international technological research, supporting the development of research projects and initiatives that contribute to technology development. We are pleased to see how participation in these global projects is shaping the Polish space sector, enabling mutual exchange of experience and building strong relationships with other countries and institutions.

Changing approach to science teaching and working in the sector

Over the past decade, we have paid special attention to innovative approaches to science teaching. That is why we have been involved in projects such as Future Space and STEM (Science, Technology, Engineering, Mathematics) events, emphasizing the importance of introducing modern teaching methods in Polish schools. Thanks to the engaging and inspiring programs we create as part of our activities, young people have the opportunity to learn about and understand the fundamentals of scientific research and space technologies. And this is of fundamental importance for their later decision on the field of study.

Promoting careers in the space sector should be one of our important educational policies. To this end, various initiatives should be supported, such as the organization of open days, as well as scholarship programs. In this way, young people get the chance to shape their career paths and connect directly with international projects and also give them the opportunity to participate in internships at space agencies.

Directions for the next decade

At POLSA, we have been successfully combining educational activities, technology development and international cooperation for years, which we believe is fundamental for the Polish space sector. Our ambitious projects, such as the development of NSIS, the exploration of the Moon and Mars, or sending the first Polish astronaut to ISS, become a signal for young people to invest in their future. Through our hard work, we are not only bringing Poland into the permanent orbit of global exploration efforts, but also expanding the expertise of Polish entities in the country.

Investment in science and education should be seen not only as an unprecedented opportunity, but also as an obligation that has the potential to bring privileges to society as a whole. It is very satisfying to see how the growth of the space sector is benefiting not only the scientific aspect, but also the economy, providing a boost to job creation and technological innovation. ◀

Innovation Forum, December 2025

Ph.D. Eng. Robert Rajkowski with Artur Chmielewski during the Innovation Forum

The Lower Silesian Innovation Forum is currently a space for dialogue between government, business, science, and the third sector, where the most beneficial solutions for the region are developed, supporting business innovation and the development of key economic segments. This is an important forum for addressing the changing economic reality. The transformation of the automotive industry , one of the most important, will accelerate. The space sector may enter to this place.

On December 3-4, 2025, the Lower Silesian Innovation Forum dedicated to Space Technologies and Defense was held at the Wrocław Airport.

The topic was devoted to the potential of the space and defense industries as key drivers for Lower Silesia. The forum provided a meeting place for leaders in industry, science, institutions, and startups, and an opportunity to establish collaboration and exchange experiences.

During the two-day conference, issues related to the future of aerospace , space-tech and defense-tech , as well as the role of the state in the development of modern technologies in the space industry, were raised, of course focusing on the opportunities and achievements of Lower Silesia Region.

The forum was held under the honorary patronage of:
- Minister of National Defence
- Minister of Science and Higher Education
- Polish Space Agency

The Forum partners were:
- Ossoliński National Institute / Ossolineum
- Lower Silesian Innovation and Science Park

Following the example of the work [2] on activities in the field of space technologies in 2024, the program of the Innovation Forum in 2025 is briefly presented below.

DAY 1

Session 1: Opening and the role of the state

"From Lower Silesia to the World" – Awards Ceremony of the Voivodeship Competition for Innovative Companies Planning to Expand Abroad

From Lower Silesia to space
- Jędrzej Kowalewski (Scanway)
- Prof. Arkadiusz Wójs (Rector of the Wrocław University of Science and Technology)
- moderator: Maciej Myśliwiec (Space Agency)

Issues of cooperation between science and the space sector were discussed, pointing out the need for close cooperation also in the preparation of appropriate personnel.

Opening Panel: Space, Science, and National Security
- Piotr Mierzejewski (Thorium Space)
- Zbigniew Jagiełło (Former President of PKO BP bank, Creator of BLIK system)
- Justyna Redełkiewicz -Musiał (Go-Cosmic)
- Maciej Myśliwiec (Space Agency)
- Dr. Milena Ratajczak (New Space Foundation / Astronomical Observatory of the University of Warsaw)

Session 2: Cosmic Inspiration Poland looks to the stars
- Space themes in Marka Polska - Prof. Barbara Mróz-Gorgoń (Think Tank Marka Polska)
- V4 Space Summer School in Lower Silesia in 2026 - Jan Pomierny (New Space Foundation), Dr. Radosław Zajdel (Geodetic Observatory Pecný / Wrocław University of Environmental and Life Sciences)

Case Study : CAMILA – Polish satellite constellation under construction
- Piotr Owdziej (cc group) & Jakub Bochiński (Creotech)

Keynote Speech – Artur Chmielewski (NASA / Jet Propulsion Laboratory)

A mission that inspires – how they use the Ignis mission to promote the sector
- moderator: Dr. Milena Ratajczak (New Space Foundation / Astronomical Observatory of the University of Warsaw)
- Prof. Barbara Mróz-Gorgoń (Think Tank Marka Polska)
- Jan Pomierny (New Space Foundation)
- Artur Chmielewski (NASA / Jet Propulsion Laboratory)
- Justyna Redełkiewicz -Musiał (Go-Cosmic)

The special guest at the Innovation Forum was, of course, Artur Chmielewski, who delivered a fascinating lecture and participated in discussions and behind-the-scenes conversations during the conference. He proposed cooperation between Lower Silesia and NASA units, urging them to define common tasks and goals. He is open to the development of Polish-American cooperation at various levels and in various areas important to both Poland and the United States.

Session 3: Competency development – staff, education, cooperation Conversation: Future Security – Space, Data, Cybersecurity
- Colonel Marcin Mazur (Polish Space Agency)
- Interview by : Dr. Joanna Baksalary (Association of Polish Space Sector Professionals)

Fireside chat: Space innovations through the eyes of the military

- Brigadier General Marcin Górka (Ministry of National Defence)
- Interview by: Dr. Milena Ratajczak (New Space Foundation / Astronomical Observatory of the University of Warsaw)

Space technologies and future security

- moderation – Paweł Pacek (ARP)
- Kamila Matela (Radmor)
- Piotr Mierzejewski (Thorium Space)
- Mateusz Wolski (Astronika)
- Sebastian Magadzio (Airbus Poland)

During Session 3, security issues were discussed at length, as demonstrated by the conflict in Ukraine. This issue is crucial to the country's security and should be intensively developed from a practical perspective now.

DAY 2

Session 1: Financing the Space Sector "European money for space"

- Monika Banaszek - Cymerman (Polish Space Agency)

"Polish support measures for space companies"

- Mardoniusz Maćkowiak (cc group)

Panel: How to Raise Capital for Space? VC, Banks, Grants / Financing Defense in Space

- Michał Karbowiak (Head of Business Development Zeccer / Portfolio Manager RST LIFT OFF Startup Accelerator
- Krzysztof Górka (Lower Silesian Development Fund)
- Maciej Frankowicz (Hard2Beat VC)
- Wojciech Drabczyński (Balnord)

Case study : "Our path to financing"

- Mardoniusz Maćkowiak (cc group)
- Jędrzej Kowalewski (Scanway)

Session 2: Business and the Regional Ecosystem
Current trends and innovations in the space industry

- Dr. Martyna Gatkowska (IAC 2027 Local Organizing Committee)

Lower Silesia in space – a showcase of Lower Silesian companies

- Nanores Lab - Mateusz Dziubek (Application Engineering Team Leader)
- SatRev
- Thorium Space - Milena Bobińska (Head of Business Line)
- GISPartner

How to strengthen the Lower Silesian industry?

- moderator: Dr. Martyna Gatkowska , who represented the National Committee preparing IAC 2027, which will be held in Poznań.
- Prof. Witalis Pellowski (Academy of Land Forces, Wrocław)
- Bartłomiej Kubicz (Marshal's Office of the Lower Silesian Voivodeship)
- Paweł Modrzyński (Nanores Lab)
- Dr. Daniel Więzik (SatRev)
- Paweł Pałubiński (Collins Aerospace Wrocław)

SatRev deserve special mention ; it has placed several satellites in space, also for domestic universities, and has recently been offering services related to information from space.

Session 3: Competency development – staff, education, cooperation
Personnel for space

- Justyna Pelc (ResQuant)

Business Needs: What talents are needed?

- moderator: Sylwester Wyka (Astronaika)
- Jadwiga Gębka (Collins Aerospace Wrocław)
- Mikołaj Podgórski (Scanway)
- Dr. Joanna Baksalary (ITTI)

Scanway , a company specializing in optical instruments, are also noteworthy . The experience of Collins Aerospace , which has been employing space technology professionals for many years, is also significant.

Education–Business–Government: A Common Mission for Space

- Paulina Brym- Ciuba (StartUp Hub Poland)
- Michał Pilecki (Polish Space Agency)
- Prof. Damian Derlukiewicz (Wrocław University of Technology)
- Adam Zagrajek (CleverHive)

How do we train staff for the space sector?

- moderation: Justyna Pelc
- Prof. Krzysztof Sośnica – University of Environmental and Life Sciences in Wrocław
- Prof. Piotr Wrzecioniarz - National Committee for Space Technologies
- Janek Adamski and Marcelina Wawrzyńczyk (High School No. XIV named after the Belgian Polonia)
- Dr. Eng. Adam Jaroszewicz - Wrocław University of Science and Technology

The final panel was very dynamic, focusing on staff training. Professor Sośnica announced the creation of a program of study related to space applications, which is very popular among students. Professor Wrzecioniarz spoke about the need for parallel education at all levels, from preschool to doctoral studies, as is the practice in development centers in the US and China. He also touched on the passionate education model known from science students group. The high school students supported the ideas presented by the other panelists, hoping that the youth of Lower Silesia will be well prepared for careers in the space sector.

Summary

The second day concluded with a summary and closing of the conference. Participants emphasized the importance of the conference and its relevance to the global geopolitical situation. During the sessions and in the lobby, various new ideas for organizing future conferences on space issues were discussed. Further activity by the scientific, business, and local government communities in the areas of space technology applications and education for the needs of tomorrow's developing industry is anticipated. ◀

Source materials

[1] Innovation Forum conference program December 3-4, 2025
[2] Wrzecioniarz, P. "The origin and purpose of the National Committee for Space Technologies", "Przegląd Komunikacyjny", no. 7-8, 2025.

Poland after world war III

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1. Introduction

The world is currently undergoing turbulent development. Preparations for a world war are underway. Geostrategists have been analyzing the changing international situation for several years now. Further dates and potential locations for a major conflict are being set. The topic is common knowledge in many parts of the world.

Cities have been selected for nuclear attack, and potential spheres of influence have been defined. Since 2022, industrial companies have been preparing for what may soon happen. As a society, we are receiving information and even instructions, such as a "safety guide," on how to behave in this hour of testing.

This paper presents several general observations based on, among other things, known history and the many discussions that have been taking place in Lower Silesia over the years. It also outlines development concepts that could be implemented after the end of any potential conflict.

2. A few comments about our activities in Lower Silesia

In the Lower Silesian region, things really began after the economic transformation of the 1990s. At the Krzyżowa Foundation for European Understanding, during a period of high unemployment and the exodus of educated people from Poland, we formulated a development strategy, including industrial development. Everything worked out for us. Lower Silesia is one of the most dynamic regions in Europe and, after Warsaw, the most developed, with relatively high wages and a large number of educated people working in high-tech fields.

We noticed the changes taking place in the world very quickly. In 2019, we launched another initiative in Wrocław: the G2 Forum – Geopolitics and Economy. Anticipating further changes that would occur in the global economy, it was there that we first began discussing a potential global conflict . The discussion was attended by both civilian and military strategists, from government and local government units, as well as from professional think tanks emerging in Poland at the time. Based on this knowledge, this article presents some forward-looking topics.

It's worth noting that in 2019, Konrad Tomaszewski launched the "Genius Loci" Salon, which connected people from culture, art, science, technology, and politics. One of the events, which took place over several days at the castle in Trzebieszowice, was my "SMS" (Strategic Thought Salon).

Further considerations presented in this study result, among other things, from participation in all the events mentioned and the discussions held there.

3. Historical outline

Using increasingly efficient AI systems, we've compiled basic, synthetic information about World Wars I and II to provide a preliminary extrapolation of what a third world conflict might look like. This is very difficult due to the many variables involved, including the significant advancement of military technology, as evidenced by General Majewski's article in this issue of "Przegląd."

Recall that the population at the beginning of World War I in 1914 was approximately 1.8 billion. The Central Powers, which de facto triggered World War I using a familiar pretext, were Germany, Austria-Hungary, Turkey, and Bulgaria. During World War I, these countries suffered approximately four million military casualties and an equal number of civilian casualties, for a total of eight million casualties.

The Entente powers, which joined successively, included France, Great Britain (with its dominions), Russia, Serbia, Montenegro, Belgium, Japan, Italy, Portugal, Romania, the United States, Greece, China, Brazil, and many smaller nations. In total, this group included as many as 30 countries. The total number of military casualties in this group was approximately 6 million, and the number of civilian casualties was similar, bringing the total losses in the Entente states to approximately 12 million.

Adding the losses of the Central Powers and the Entente Powers, the number of victims during World War I was approximately 20 million. This represents approximately 1.1% of the population at the time.

Losses in World War II were significantly greater. The beginning was very similar, with Germany once again starting the war by challenging the terms of the Treaty of Versailles. After five years of global conflict, the final outcome could be summarized, as shown in Figure **1** for Europe.

Tab. 1. Results of World War I and II

Year	Population	Killed	[%]
1914	1.8 billion	20 million	Approx. 1.1%
1939	2.3 billion	80 million	About 3.5%
2027	8.3 billion	500 million	About 6%

In Poland, losses amounted to 5.9 million people, representing approximately 17% of the country's population. As you can see, Poland suffered the greatest losses. We do not want a similar scenario in a third world conflict. A summary for both wars to date is presented in Table 1, with data extrapolated for the next conflict as well.

The information provided for World War III is an estimate and subject to significant uncertainty. We don't know how large the conflict will be, what part of the world it will affect, when it will begin, or what the losses will be. They could also be greater than those given in Table **1**. Furthermore, given the continued increase in casualties, we estimate this figure for World War III at 6%, assuming a sense of calm will come and the escalation will ultimately be halted.

Let's recall a few areas characteristic of past and present conflicts. Examples from well-known locations are summarized in Figures **2**-**7**. Many more similar images can be found online.

Considering the accumulated arsenals and the current 50 or so local conflicts, significantly greater losses are conceivable. This is, in a sense, a positive scenario, assuming that:

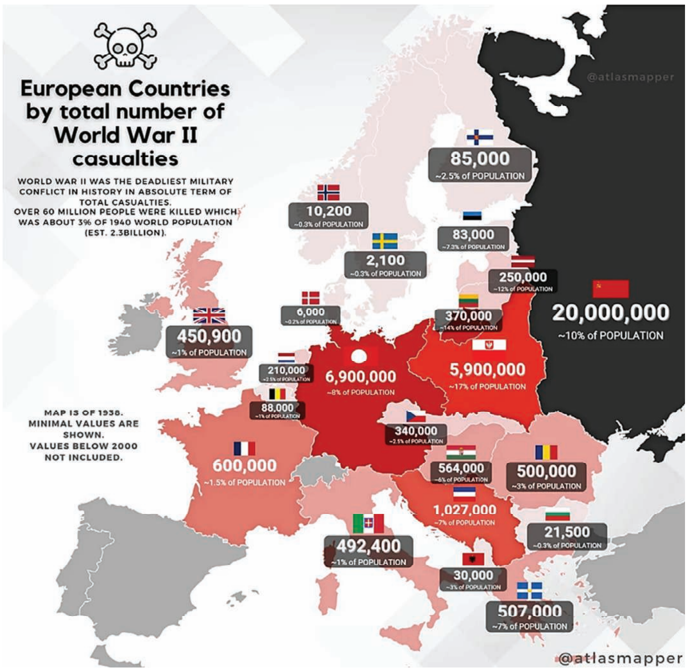
- publishing alarmist predictions will prevent the outbreak of war,
- If World War III breaks out, there will be a moment of reflection and after reaching a certain level of destruction, the conflict will be over and the total destruction of the globe will not occur.

Let's also recall that over the past 4,500 years, Wikipedia has documented 10,600 battles and wars that took place in our European and Mediterranean cultural area. Remember, this description only refers to written information. In reality, there were many more conflicts worldwide.

The two world wars to date have taught us that networks and areas of cooperation are created ad hoc, that all alliances are fickle, and that after the war ends, dissatisfied parties always emerge. Organizations like the League of Nations failed when confronted with the selfish agendas of individual states, much as the UN does today. We will briefly review the strategies known in Poland after 1945. Figure **8** presents the Polish front's attack plans on Western Europe, within the framework of the Warsaw Pact.

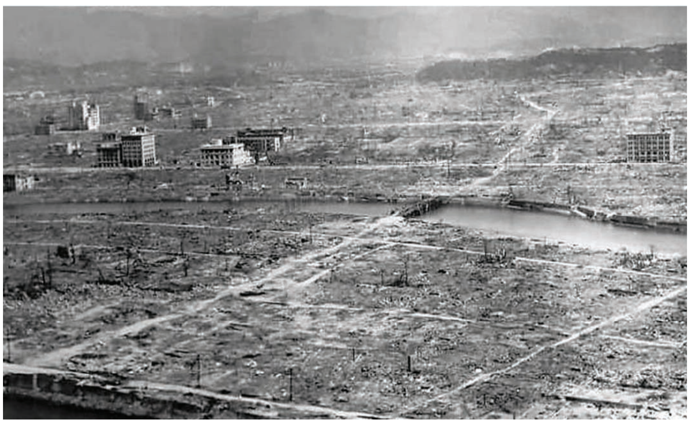
First Army was to reach northern Germany and then Denmark and the Netherlands, while the Second Army was to first occupy Germany and then reach Belgium. This strategy was in effect in Poland under Soviet occupation. In 1989, this strategy changed. Poland joined NATO in 1999 and the

1. Pablo Picasso - Guernica – a symbolic image of World War I



2. Losses of European countries after World War II

3. Ruins of Warsaw – World War II



4. Ruins of Hiroshima – World War II

5. Ruins of Aleppo – beginning of the 21st century

6. Ruins of Gaza – 2020s

7. Ruins of Mariupol – 2020s

8. Plan of attack of the Polish front on Western Europe

European Union in 2004. Poland's eastern border is also NATO's eastern border. Meanwhile, the concept of a defense line on the Vistula River emerged, which is now public. It divided Poland along the Vistula into western and eastern parts, as shown in Figure **9**. This would be the border between the European Union and Russia, effectively preparing the fifth partition of Poland, very similar to the borders of the fourth partition of Poland in 1939, although it runs even further west.

This study assumes that Poland will not be completely destroyed during World War III, that there will be no "Battlefield of Europe" as there was during previous major conflicts. It is assumed that World War III will begin far from here and end without the major devastation in our country, as was the case previously. Then, the possibility of creating a buffer zone between Western Europe, which is currently culturally and historically united, and Eastern Europe, or the conventional EEC – East European Countries, will re-emerge. It is worth noting that large industrial companies divide our region in this very way. The author had the opportunity to experience this firsthand while working for the global oil company Shell. Certain groups of issues were common across the Baltic states and Greece. So, while certain solutions are already in place in business, can they also function in the political world? Local alliances are currently being formed in many places around the world. It is quite obvious that local alliances will play a significant role here, and what happens will be the result of all these forces and resources. This article presents what we believe to be the ideal solution: separating Eastern and Western Europe and creating a zone of states sufficiently strong economically and militarily to divide Western Europe and the Russian Empire. The following figures present the arguments for such a move. Figure **10** shows that by 2024, Poland's economic strength will be equivalent to that of the countries to its east.

Poland is the leader in this endeavor. The goal isn't to dominate neighboring countries, but to cooperate with them. We demonstrated this in 1980 by creating "Solidarity," which brought freedom to all. At the heart of this movement was the equality of both people and states. It was Poland that formulated the ideas of Solidarity between states and led to the peaceful transformation of the communist system . We've already accomplished this once. Now it's about dividing East and West in the name of the great Solidarity.

Poland, the world's 20th-largest economy with an income of approximately $1 trillion, is equivalent to all the countries to its east. Together, we can be a significant force. Figure 11 shows the potential division of the Western and Eastern worlds according to current maps, including northern European countries.

It should be noted that the countries of Central and Eastern Europe can be grouped historically (the Eastern Bloc), politically (the Visegrad Group), according to their membership in the European Union (CEE – Central-East-Europe), geographically (the Baltic, Balkan, post-Soviet states), and within the framework of international co-operation (the Eastern Partnership). This area includes the V4 (Poland, the Czech Republic, Hungary, Slovakia), the Baltic states (Estonia, Latvia, Lithuania), the Balkan states (Bulgaria, Romania, Croatia, Slovenia, Serbia, Montenegro, North Macedonia, Albania), the post-Soviet states (Ukraine, Belarus, Moldova), and the Caucasus states (Armenia, Azerbaijan, Georgia).

This group should include the Scandinavian countries of Sweden, Finland, and Norway. It's worth noting that this division is already in place in business and has proven effective in practice. After the end of World War III, it may become the standard for this part of Europe.

It's unclear how the maps will shape up after World War III, but it's suggested that this belt between the two parts of the continent should also include the Scandinavian countries. The first attempts in this regard were made during the G2 Forum, where this diagram was presented during a panel discussion on cooperation in space. Our goal is for countries from Scandinavia to Greece to work together for the good of all of us, but also for the good of all of Eurasia. We hope this concept will gain interest from various economic bodies, which will then convince political ones.

It should also be emphasized once again that we do not want to divide Europe. However, recent wars have demonstrated that the interests of individual parts of Europe were divergent. Poland was abandoned to its own devices by Western European countries at the beginning of World War II, and by the end of the war, a significant portion of it was taken and the remainder placed under Soviet occupation for 45 years. Both aggressors of World War II, through the "Intelligenzaktion" (Germany) and the persecution of the Home Army opposition, significantly weakened the Polish state. Only now have we rebuilt it. The behavior of interest groups from various countries around the world towards Ukraine also astonishes us, especially since the Ukrainian population is suffering. We do not want any more of this type of action in Poland or in the aforementioned countries belonging to the contractually enlarged EEC.

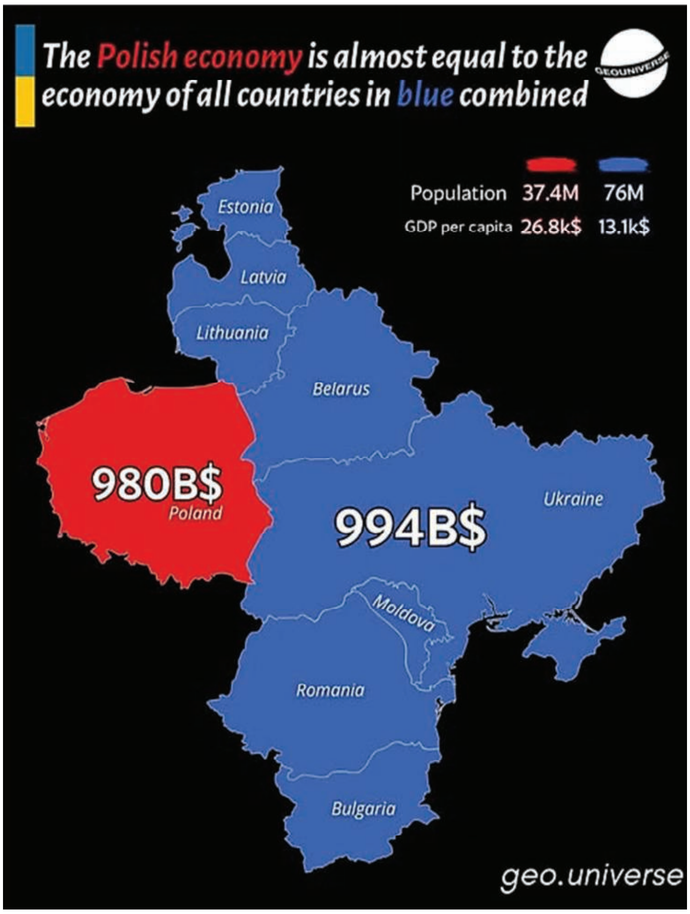
This is another voice related to peace in our part of Europe and the world. Let's try to set an example by organizing everything peacefully. We can start now and try to stop the impending conflict, at least for all stakeholders in this part of Europe.

If you have any questions or concerns, please contact us directly.

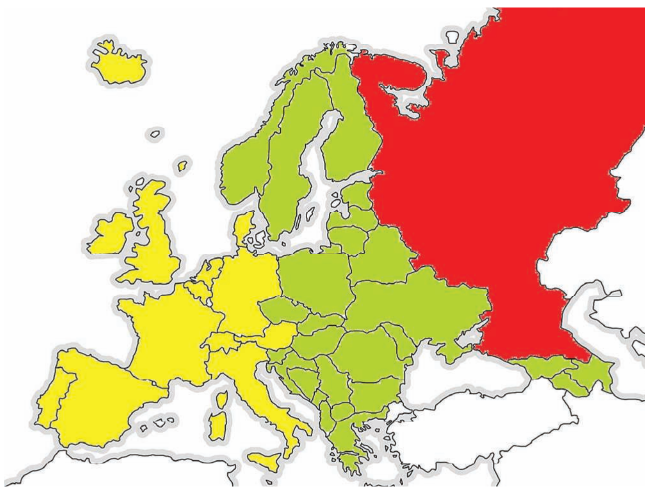
Piotr A. Wrzecioniarz

- The originator of the Lower Silesian Economic Certificate at the Forum in Krzyżowa,
- Chairman of the G2 Forum Program Council,
- Chairman of the National Committee for Space Technologies,
- The originator of the Strategic Thought Salon as part of "Genius Loci"◀

***9**. Defense line on the Vistula*



***10**. GDP of Poland and countries located to the east of Poland*



***11**. The potential separation of the Western world and the Eastern world of Europe*

MIRORES: MIR/FIR Space Spectrometers for Lunar and Terrestrial Geological Prospecting

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Abstract: MIRORES is a compact mid-infrared (MIR) to far-infrared (FIR) spectrometer designed for geological prospecting on the Moon and Earth. It covers the 6–20 µm range (optionally extending to ~45 µm) at ~0.5 µm spectral resolution, enabling detection of mineral signatures (e.g., phosphates, oxides) not observable with visible/near-infrared sensors. A 256×320 focal plane array (with 16 narrowband channels of 20 rows each) and two additional detectors for apatite and ilmenite, paired with a lightweight optical system, delivers robust performance in both lunar and terrestrial applications. Field trials and integration plans demonstrate technical readiness and strategic alignment with space resource initiatives

Keywords: *Infrared Spectroscopy; Remote Sensing; Ore geology; Space Resources*

Introduction

Advances in mid-infrared remote sensing are opening new frontiers for mineral exploration on planetary surfaces. The 6–45 µm wavelength range contains diagnostic vibrational bands of water ice and many minerals (oxides, sulfides, and phosphates) that are not detectable in the visible-to-short-wave infrared (VNIR/SWIR) spectrum used by most previous missions. For example, the lunar mineral apatite (a calcium phosphate) has a strong absorption band near 17–18 µm, and ilmenite (an iron-titanium oxide) shows a band around 19 µm. These signatures lie beyond the reach of instruments such as NASA's Moon Mineralogy Mapper (which operated at <3 µm). They are only partially covered by the Lunar Reconnaissance Orbiter's Diviner radiometer, which has three of its four IR channels clustered near 8 µm [1]. As a result, critical resources such as phosphorus and rare-earth elements in apatite, and oxygen and helium-3 in ilmenite, remain challenging to prospect with traditional VNIR/SWIR sensors. MIRORES has been selected as the primary science payload for an upcoming lunar orbiter mission (the Lunar Mineralogy Mapper, under development by ESA) scheduled for launch in 2029. This mission will mark the first deployment of a far-infrared spectrometer around the Moon, and MIRORES will thus become a pathfinder for lunar resource mapping from space.

The MIRORES (Mid-/Far-Infrared ORE Spectrometer) instrument is conceived to fill this gap. Developed initially to detect sulfide ores on Mars in the 20–30 µm FIR range, MIRORES has been re-engineered to focus on the 6–20 µm MIR region (with extension to ~45 µm) that addresses high-priority lunar resources while maintaining compact size and feasibility. This shift leverages the fact that apatite and ilmenite can be identified within ~6–20 µm, so extending beyond 20 µm is not essential for those goals. By narrowing the spectral scope, MIRORES achieves higher spectral resolution across the key 6–14 µm window, enabling unambiguous mineral identification against silicate backgrounds. Few spaceborne instruments have explored this MIR region for airless bodies, due in part to Earth's atmospheric opacity below ~8 µm [1]. Notably, the Japanese Himawari-8 weather satellite's Advanced Himawari Imager (AHI) sensor recently demonstrated the value of 6–14 µm lunar observations [1], validating that mid-IR spectral data can reveal surface composition differences consistent with Diviner's findings [2, 3]. Likewise, NASA's SOFIA airborne telescope detected molecular water on the sunlit Moon at 6 µm [4], a feat impossible with ground-based observatories due to atmospheric absorption. These advances underscore the scientific and exploration potential of a dedicated MIR spectrometer.

MIRORES is designed to capitalize on this potential in both the lunar context and terrestrial applications. The instrument pairs a tailored spectral range with a high-sensitivity detector and miniaturized optics to serve dual roles: flying on lunar missions to map resource-bearing minerals, and operating on drones on Earth to survey mining targets. In the next sections, we detail MIRORES's dual use as a lunar instrument and for Earth applications. These two sections are followed by the engineering design, results from initial field tests, and the path toward deployment in the space resources economy.

Lunar and Terrestrial Use Cases

The current impetus for MIRORES stems from objectives in lunar resource prospecting. Global space agencies have highlighted the need to locate and quantify in-situ resources on the Moon, water ice, oxygen-bearing minerals, metals, and other volatiles, as a foundation for a sustainable space economy in the Earth–Moon system (the so-called cislunar economy) [5]. In fact, the European Space Agency's Space Resources Strategy calls for "measurements at the Moon" by 2030 to establish the potential of lunar materials and inform their use in exploration architectures [6]. Among these materials, lunar apatite and ilmenite are particularly important. Apatite (Ca5(PO4)3F/Cl/OH) not only contains phosphorus, which is critical for fertilizers, but can also host hydroxyl or water in its structure.

Furthermore, it tends to concentrate rare-earth elements. Ilmenite (FeTiO3) is valued as a source of iron and titanium, and, importantly, it can yield oxygen and helium-3 via chemical processing, making it a key regolith constituent for future ISRU (in-situ resource utilization) oxygen and helium-3 production. In 2025, Interlune announced a first-of-its-kind agreement with the U.S. Department of Energy Isotope Program to purchase 3 L of lunar-derived helium-3 by 2029, and a parallel industrial contract under which Bluefors may buy up to 10,000 L of helium-3 annually between 2028 and 2037, indicating the emergence of an early commercial market for this isotope (interlune.space). Identifying rich deposits of these minerals on the Moon would directly support plans for crewed lunar bases and fuel generation. However, traditional orbital imagers such as the Moon Mineralogy Mapper (M3), which operate in the 0.4–3 μm range, or even thermal mappers like Diviner (~7.5–23 μm) have limited capability to pinpoint apatite or ilmenite. These minerals' distinctive vibrational bands either lie outside the range measured so far or fall into coarse, overlapping channels [1]. Therefore, a specialized spectrometer, such as MIRORES, is needed to map these resources with confidence.

Although MIRORES originated as a lunar-focused project, it was conceived with Earth applications in mind as well. The spectrometer's wavelength coverage overlaps an atmospheric window (~8–14 μm) that is exceptionally useful for geological remote sensing on Earth [7]. In this thermal infrared region, emitted radiance from rocks carries mineral-specific signatures that can complement reflected-light (VNIR/SWIR) spectroscopy [8]. For instance, quartz-rich rocks, carbonates, clay minerals, and sulfates each exhibit unique reststrahlen bands or Christiansen features in the 8–14 μm range. Reststrahlen bands arise from strong fundamental vibrational absorptions (e.g., in Si–O or C–O bonds). Christiansen features correspond to local emissivity minima near wavelengths at which the real part of the material's refractive index approaches that of the surrounding medium [7,8]. These characteristics enable lithologic mapping that is difficult to achieve at shorter wavelengths [1]. Airborne and satellite sensors (e.g., NASA's ASTER and HyTES instruments) have exploited this window to map Earth's surface mineralogy, taking advantage of high transmission in the 8–12 μm interval [7]. However, absorption by atmospheric water vapor severely hinders observations in the 6–8 μm spectral region from the ground or orbit [1]. Here, a MIRORES unit, deployed on a low-flying drone or on site, could directly measure the 6–20 μm spectra of rocks with minimal atmospheric interference. Using drones opens up opportunities for mineral exploration in remote regions: a UAV-mounted MIRORES could scan for phosphate ore bodies (apatite-rich) or titaniferous sands (ilmenite-rich), both of which are of growing economic interest. The International Energy Agency projects a threefold to sevenfold increase in rare-earth element demand by 2040 due to clean energy technologies [9], and a parallel surge in demand for battery and photovoltaic minerals [9]. Developing portable MIR spectrometers for rapid reconnaissance of such critical minerals can help meet this demand. In essence, the same spectral tool that surveys lunar highlands for resources could survey arid terrain on Earth for new mineral deposits. A direct technology transfer from space exploration to terrestrial industry is therefore made. Future missions to the Moon are also viewed as both a testbed for sustainable exploration and a driver of economic benefits on Earth through knowledge of the Moon's resources [5]. MIRORES fits into this vision by providing a tangible, dual-use capability: a spectrometer that will serve lunar missions and subsequently the mining and geoscience sectors on Earth.

Spectral Engineering: Compact and Capable

Designing an imaging spectrometer for mid- to far-IR geological prospecting poses challenges in sensitivity, resolution, and size. MIRORES addresses these with a purpose-built detector matrix and optical layout that balance performance with compactness. At its core, there will be a two-dimensional 256 × 320-pixel focal plane array (FPA), composed of two matrices, each 256 × 160 pixels. These two mercury-cadmium-telluride (HgCdTe) matrices are cryogenically cooled and optimized for the 6–10 μm and 10–14 μm wavebands, respectively, offering high specific detectivity (D* ≥ 10^10 Jones). MIRORES leverages the 2D arrays by dividing them into spectral sub-arrays: the 160-pixel-high dimension in both matrices (320-pixel-high altogether) is conceptually segmented into 16 strips of 20 lines each, enabling the capture of 16 distinct wavelength bands. In practice, this multiplexing is achieved using discrete interference filters that spread different portions of the spectrum across designated detector rows. MIRORES's implementation dedicates ~20 detector rows per spectral channel to ensure sufficient signal integration. Therefore, the instrument can simultaneously measure at least 16 narrow bands across a 6–14 μm range without moving parts, a significant advantage for mapping specific mineral fingerprints. The spectral resolution is ~0.5 μm. To resolve adjacent features such as the 17.5 μm vs. 19 μm bands, the design includes a diffraction grating that directs those wavelengths to pyroelectric detectors, bringing the total number of spectral channels to 18.

MIRORES uses a two-mirror Cassegrain telescope design that is folded into a small volume. In the original Mars-oriented design, the primary mirror diameter and focal length were chosen to achieve ~10–20 m/pixel ground resolution from orbit [10]. For the lunar mapping scenario, the requirements have been relaxed to a spatial sampling of ~100 m/pixel (since the focus is on identifying large-scale resource-rich areas). This relaxation allows a wider ~10° field of view without increasing the optics size (consistent with ESA constraints) or requiring significant changes to the telescope or cooling design. The primary mirror is 30 cm in diameter (sufficient to collect mid- to far-IR light over the FOV), and the entire instrument mass is under 10 kg (Fig. **1**), fitting within a microsatellite form factor [11]. Half of the light from the telescope's secondary mirror passes through an aperture directly to the filter system, which partitions the spectrum into designated detector segments. An additional diffraction grating for the other half of the light diffracts the 17.5- and 19-μm wavelengths to the pyroelectric detectors for apatite and ilmenite. The same diffraction grating can also serve to diffract light to optional detectors for sulfides with spectral features between 24 and 39 μm [10, 11] and for water ice around 43 μm [12], for adopted versions of the MIRORES spectrometer for sulfide prospecting on Earth or water ice prospecting on the Moon. In any case, a longwave-pass filter will be used to cut off wavelengths below 6 μm and ensure temperature-invariant performance in the MIR/FIR.

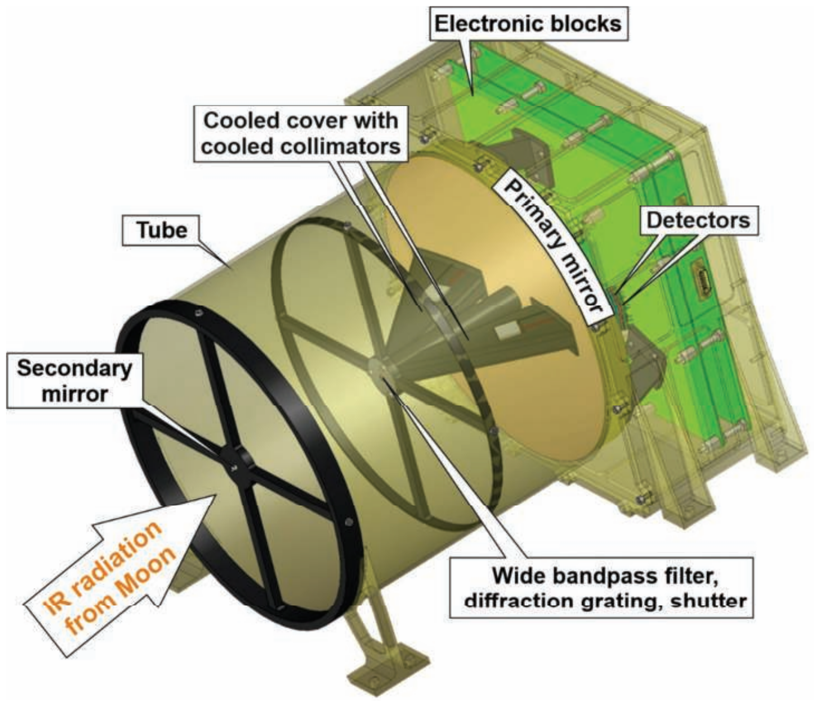
Thermal control is vital for a mid- to far-infrared instrument. A miniature cryocooler (e.g., TC2570) will cool MIRORES's space-based detectors to maintain the required low temperature for low noise. The optics will be thermally stabilized near 0 °C to prevent mechanical deformations. In contrast, the semiconductor detectors must be cooled to 50–100 K, and the space between the diffraction grating and the detectors is maintained at about 190 K. In the current design, modern cooled photonic detectors (HgCdTe) offer far superior sensitivity, so they have been adopted despite the need for cryogenic cooling. The electronics incorporate integrated amplifiers for each detector channel and a multi-channel readout to handle the 81,920 pixels (256×320) at video rates. Data can be processed on board to convert the raw signals into calibrated spectral radiance for each band. The spectral calibration uses reference observations and known blackbody sources; radiometric accuracy better than 5% is targeted, in line with mission requirements.

Field Trials and Terrestrial Integration

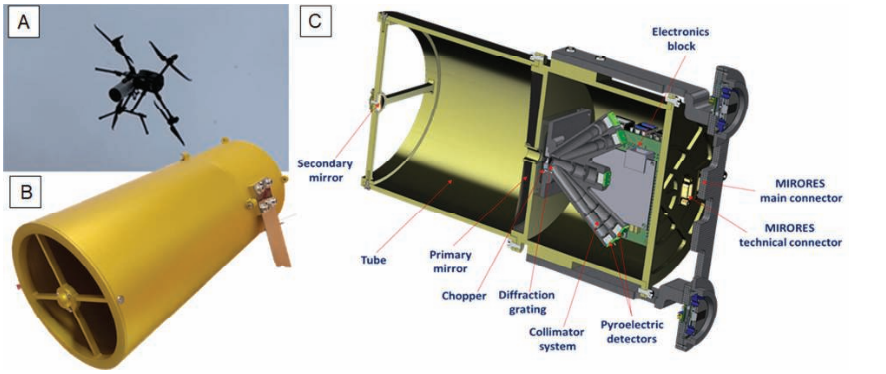
To bridge the gap between design and deployment, MIRORES is undergoing stepwise testing under laboratory and field conditions. Initial validation has focused on its core function: distinguishing target mineral signatures in mixed scenes. In the laboratory, powdered mineral samples (e.g., apatite, ilmenite, pyrite) are analyzed with various IR spectrometers to generate reference spectra and simulate MIRORES's band responses. Simulations based on these measurements confirmed that ilmenite and pyrite bands can be detected even when these minerals constitute as little as ~10% of a powdered mixture with silicates, given MIRORES's spectral resolution and signal-to-noise [10, 11]. Such studies increase confidence that the instrument will detect ore minerals against a regolith background [10, 11]. Finally, a MIRORES prototype is used to acquire mid-far-infrared spectra of the same samples, confirming that the diagnostic bands identified in the simulations are observable with the instrument itself.

In parallel with static tests, the team has begun integrating MIRORES onto a drone (Fig. **2A**). The low mass (<3 kg) and power consumption (10 W) of MIRORES make it feasible to fly on a medium-sized drone, such as a DJI Matrice 350, for surveys of tens of hectares. MIRORES can fly over rock outcrops and open-pit mines containing various ore minerals. An autonomous scanning mode is envisioned in which the drone sweeps the spectrometer's field of view over a grid, producing an absorption spectral map. Although atmospheric conditions influence mid- to far-infrared sensing from an airborne platform, flights at low altitude (50–100 m) in dry conditions can minimize absorption by water vapor. Furthermore, bands beyond ~12 μm (e.g., 17–20 μm) can be partially corrected using the drone's onboard atmospheric humidity sensors. MIRORES is also being adapted for stationary deployments (e.g., scanning ore on conveyor belts in mines) or even as a handheld mineral analyzer (Fig. **2B** and **2C**).

Results from ongoing tests are guiding final engineering tweaks. For example, if strong ground vibrations are found to affect the detector, additional damping mounts can be implemented. The following steps will involve increasing the prototype's autonomy and robustness. A fully self-contained unit (with onboard calibration sources and data processing) is in development for longer-term field deployment, potentially in mines or at exploration sites. By demonstrating operations outside the lab, the MIRORES team is lowering risk



***1**. Scheme of the MIRORES Moon instrument (30 cm diameter). Redrawn from [12]*



***2**. (A) The MIRORES spectrometer adapted for drone mounting (13 cm aperture). (B) A 15 cm-diameter MIRORES unit designed for use over conveyor belts or as a handheld device. (C) Technical schematic of the same 15 cm unit for industrial/handheld use*

for eventual use in space and building credibility for use in terrestrial industries.

Future Outlook and Strategic Vision

MIRORES is on a fast-track trajectory from concept to deployment thanks to its alignment with current exploration initiatives. The instrument has been selected as a baseline payload in a Phase A study for a prospective lunar mission, where its ~6–20 µm MIR capability fills a noted gap in the mission's science requirements. Under this ESA-sponsored Phase A of High-Resolution Lunar Mineralogy Mapper, the team is refining MIRORES's flight design to ensure that the field of view, spectral resolution, and other parameters meet the spacecraft's constraints. Over the next 1–2 years, the team aims to raise the space instrument's technology readiness level (TRL) from the current ~5 (component validation in the lab) to TRL 7–8 by building an engineering-qualified model and a flight model. These models would undergo thermal-vacuum testing, vibration testing, and radiometric calibration to simulate conditions on a lunar orbiter. The goal is to have MIRORES mission-ready by 2028 and launched by 2029.

In parallel, the strategic vision extends to commercial and scientific utilization on Earth. The push for a sustainable space economy has highlighted how technologies developed for exploration can spur terrestrial innovation [6]. MIRORES exemplifies this dual-use paradigm. As space agencies and companies invest in lunar prospecting, the same sensor can be offered to mining companies or geological surveyors on Earth as a rapid mineral-mapping tool. We foresee a service model in which MIRORES instruments are deployed (on drones or fixed platforms) to scan areas of interest identified from satellite imagery, providing high-fidelity mineralogical maps that guide drilling or extraction. Such an approach will reduce the cost and time of exploration campaigns by pinpointing ore-rich zones through remote sensing rather than extensive sampling. Early discussions with industry partners have focused on integrating MIRORES data into existing exploration workflows, for instance, using its hyperspectral thermal imagery alongside conventional airborne surveys. By keeping the instrument design modular, we can tailor it to different platforms: a vacuum-rated version for spacecraft, and an atmospheric version (with protective enclosure and cooling) for terrestrial use.

Importantly, MIRORES's emergence comes at a time when demand for critical minerals is surging. The International Energy Agency (IEA) reported in 2023 that global demand for rare-earth elements could grow 300–700% by 2040 under clean energy scenarios [9]. Elements such as phosphorus (for agriculture) and metals such as copper, nickel, and cobalt are also set to see exponential demand growth [9]. Meeting this demand sustainably will require not only mining new deposits on Earth but also, in the longer term, sourcing materials off-world. MIRORES contributes on both fronts: enabling more efficient discovery of Earth's remaining resources and characterizing extraterrestrial resources that could be a cornerstone for lunar exploration. The instrument thus aligns with a broad strategic vision shared by space agencies and industry, one in which resource mapping and utilization form a bridge between space exploration and

***Tab. 1.** Key parameters of the MIRORES spectrometer in the lunar and UAV configurations*

Parameter	Value	Configuration / notes
Lunar configuration		
Spectral range (nominal)	6–20 µm (MIR), with option to extend to ~45 µm	Continuous 6–14 µm on FPA; design optimised for MIR
Spectral resolution	~0.5 µm	For the narrowband channels on the focal plane array
Number of spectral channels	≥16 narrow bands on FPA + 2 discrete bands (17.5, 19 µm)	16 interference filter channels + pyroelectric apatite/ilmenite detectors
Detector array	256 × 320 pixels (2 × 256 × 160 HgCdTe matrices)	Optimised for 6–10 µm and 10–14 µm; D* ≥ 10^{10} Jones
Telescope	2 mirror Cassegrain, 30 cm primary mirror	Folded layout; fits within a microsatellite form factor
Field of view	~10°	For relaxed spatial sampling in lunar orbit configuration
Spatial sampling (lunar orbit)	~100 m/pixel	Designed for resource scale lunar mapping
Instrument mass	<10 kg	Complete spaceborne instrument (excluding spacecraft bus)
Detector/optics temperatures	Detectors 50–100 K; grating–detector space ~190 K; optics ~0 °C	Achieved with miniature cryocooler and thermal stabilisation
Radiometric performance	Radiometric accuracy better than 5 %	On board calibration with reference/blackbody measurements
UAV configuration		
Mass	<3 kg	Drone mounted MIRORES unit
Power consumption	~10 W	Compatible with medium size UAVs (e.g. DJI Matrice 350)
Typical survey geometry	Flight altitude 50–100 m; coverage of tens of hectares	Low altitude to minimise atmospheric absorption

Earth's economic needs [5].

In the space sector, MIRORES is positioned to contribute to upcoming missions focused on lunar geology, especially as either a primary or a secondary payload on small-satellite missions orbiting the Moon. Given its low mass and power, MIRORES could also be considered for missions to asteroids or Mars. In summary, MIRORES represents a new class of MIR/FIR spectrometers that marries technical innovation with strategic relevance to resource exploration. It advances scientific goals by filling the MIR/FIR observational gap and identifying minerals crucial to planetary science and in-situ resource utilization. At the same time, it answers a commercial call for improved mineral-sensing tools on Earth, at a moment when resource security is paramount. As humanity expands its reach to the Moon and beyond, instruments like MIRORES will be our "eyes" in wavelengths long-overlooked, guiding us to the materials that will fuel both space exploration and sustainable development on Earth.

Conclusions

MIRORES is a compact mid- to far-infrared spectrometer designed to fill the 6–20 µm observational gap for resource-bearing minerals on the Moon while simultaneously supporting mineral exploration on Earth. This dual-use space technology exemplifies cross-sector innovation: techniques developed for lunar exploration can directly enhance terrestrial mineral exploration and resource management. From a national perspective, MIRORES presents a niche opportunity for Poland in the space sector, capitalizing on domestic expertise in designing optoelectronic systems that operate reliably under high radiation levels, at very low temperatures, and in the absence of atmospheric water vapor. By combining tailored spectral coverage, high-sensitivity cooled detectors, and a compact folded optical design, MIRORES enables the detection of key ore minerals such as apatite and ilmenite from lunar orbit, UAV platforms, and fixed industrial installations. The planned maturation of the spaceborne instrument for a lunar mission, together with ongoing field trials and terrestrial integrations, indicates that MIRORES can serve as a technological bridge between space-resource prospecting and more efficient, data-driven exploration workflows in the mining and geoscience sectors.

Acknowledgements

The work was funded by the ESA SPARK project no. 1-2024/08, and the National Science Centre Poland project no. 2020/37/B/ST10/01420 to Jakub Ciążela. ◀

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Space age education

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1. Introduction

The practical space age began in the 1950s. Its origins are well known. It is generally accepted that the broader concept of modern space commercialization emerged at the beginning of the 21st century [3]. Development will continue in both the civilian and military spheres, as evidenced by the works included in this issue of "Przegląd Komunikacyjny" [1, 2].

A new industry is developing before our eyes. Countries wishing to build this type of business must not only provide adequate financial resources but also contribute to the training of human resources in the field of advanced technologies.

The development of space education in Poland to date has been spontaneous. Pioneers recognized emerging opportunities and undertook initiatives based on existing knowledge from other areas of human education and activity. For example, during a classic graduate seminar at the Faculty of Mechanical Engineering at Wrocław University of Science and Technology, "Future-oriented" fields of study were defined. In 2000, one of the graduate students at the time became interested in space issues and, along with colleagues from other institutions, became a founding member of the "Mars Society Polska," originally established by Robert Zubrin from the USA in 1998, focusing on Mars colonization and exploration projects. The then-student is currently among the founding members of the Mars Society.

Ten years later, the first private space companies began to emerge in Wrocław. Brave pioneers emerged, independently acquiring knowledge and financial resources, organizing teams and employing students and graduates from various fields of study, relying largely on space enthusiasts. Student training continued in parallel with the development of the companies. Today, we already have structures in space. The pioneering period is over. The time is coming for a broader, more systematic introduction of space topics into education.

Changes are also taking place in current growth centers. During a visit to Stanford University, the supposed capital of Silicon Valley, students were introduced to modern robotics competitions for high school students. This is preparing students from San Francisco and the surrounding area for universities and, later, for NASA space programs and private companies.

On the other side of the world, in China, primary school students are developing space robot projects, as evidenced by the work of Chinese children at the 2021/2022 Expo in Dubai, where the China pavilion showcased the work of Chinese children. During the International Astronautical Congress, which took place at the same time, several thousand participants from around the world were able to see these works. It's also worth noting that Chinese children are now familiarizing themselves with AI technologies from a very young age, just like children in the United States.

Based on these signals coming from both growth centers, this study presents some of the experiences gained in our country in the field of space education, as well as considerations that can be used in teaching not only by teams operating in Lower Silesia.

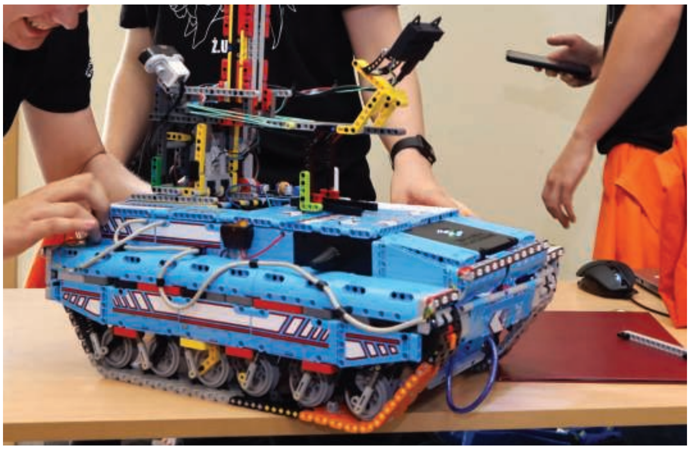
2. Selected trends in education

There are many studies on the development of education. This study will present ideas related to technology in its broadest sense. The choice is dictated by the fact that Poland is already the 20th largest economy in the world. Entering the top 15 will be possible provided that we maintain development comparable to what we have achieved over the last 30 years, taking into account global trends. Therefore, our choice is primarily related to further development in the field of technical sciences, which, as is widely known, are ahead of other fields [5, 6, 7, 8].

Regardless of culture, country, or part of the world, STEAM (Science – Technology – Engineering – Art – Mathematics) education is currently considered paramount to the further development of civilization. Sometimes, the development of TED (Technology – Entertainment – Design) is also discussed.

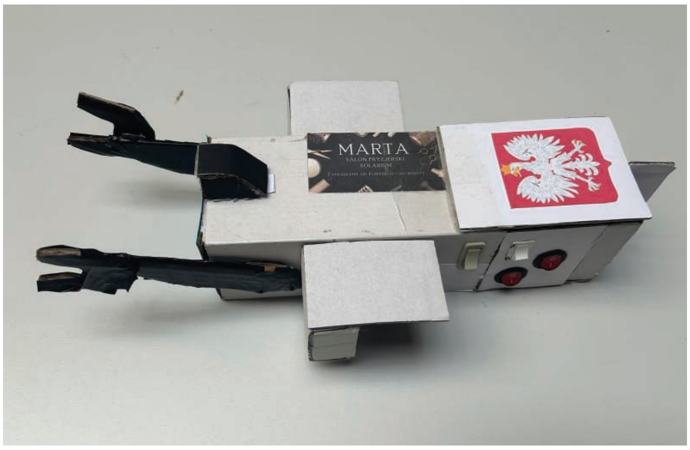
It is obvious that other areas, such as creative problem-solving techni-

1. Collegium Witelona



2. Collegium Witelona

3. Collegium Witelona



4. Instytut Inwentyki

ques, teamwork, and healthy competition in areas related to new technologies, etc., contribute to significant development. However, they will not be considered here.

With decades of experience in technical creativity at the university level, following the example of top American technical universities such as Stanford and MIT, similar efforts were undertaken in Poland over 20 years ago to collaborate with schools. Some of these experiences are described below.

3. Examples of teaching experiments

3.1. Teaching and the time to implement innovation

Based on collaborations with companies such as TUV, Mercedes-Benz, Volkswagen, 3M, Porsche, and KGHM, more general conclusions can be drawn. Researchers' activities generally require rapid, effective implementation at the highest global level, ensuring the company's leadership in a specific area of activity. Implementation time should be short.

In the case of our students, we prepared them during their final years of studies to develop the companies they would join or to found their own academic companies in entirely new areas. This happened in the space industry. In this case, implementation and immediate success were virtually impossible. It took pioneers three to five years to achieve progress and significant success.

It is known that in the case of secondary schools, it is generally necessary to prepare young people for work more than 10 years in advance of completing school and higher education.

In the case of the first grades of primary school, this period is already over 15 years.

It is obvious that teachers do not have knowledge that far into the future.

Let us also remember that over the last half-century, there has been

SPACE, AVIATION ➔, AUTOMOTIVE INDUSTRY➔

5. Classic knowledge transfer

a transfer of knowledge in technical sciences, as shown in Figure **5**.

This transfer resulted from significant financing of space issues by state entities, and the use of technology took place in other sectors of the economy, including large-scale production.

Currently, in the era of space commercialization, companies are leveraging other areas of human activity and transferring knowledge in the opposite direction, i.e., to the space industry, for example, significantly reducing unit production costs. Therefore, the development and accelerated commercialization of space require a different approach to education. Linear development will take too long. A parallel model is required.

A description of sample activities is included in the next part of this text.

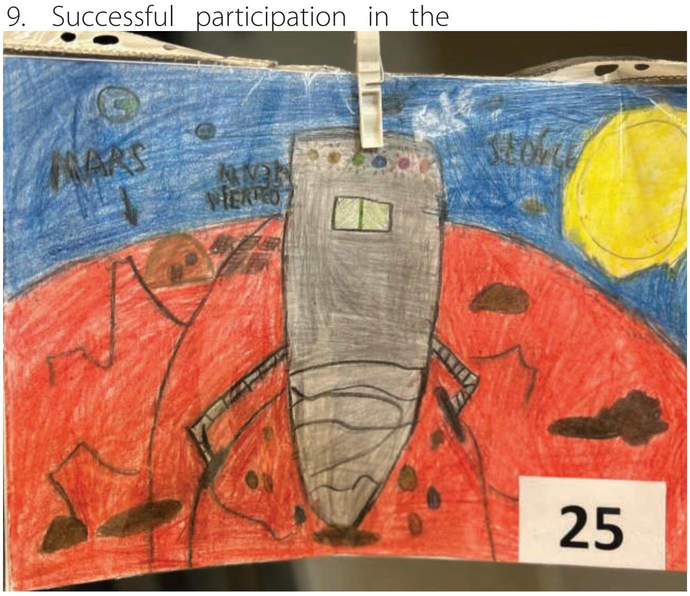
3.2. A Brief History of School Robotics [4]

This chapter presents milestones related to the general development of robotics (items 1-16) and, in more detail, practical activities in the field of school robotics (items 17-36), carried out in Wrocław, Lower Silesia, and finally throughout the country. It is clear how the transition from classical robotics to space robotics took place. This process took over 20 years.

1. Review the MITI reports on the future of robotics (Oxford 1985).
2. Initial design of a Polish autonomous vacuum cleaner based on the "Zelmer" brand (1992).
3. Design and construction of the first Polish autonomous robot "Wrocławik" (2004).
4. Design and construction of the first Polish anthropomorphic robot "Prof. Wrocławski" (2006).
5. Construction of a laboratory for collaborative autonomous robots at the Department of Vehicles of the Faculty of Mechanical Engineering of the Wrocław University of Science and Technology (2007-2010).
6. Construction of nanosumo, minisumo and sumo robots (2011).
7. Visit to Stanford University and NASA (2012).
8. The first Polish Autonomous Vehicle based on the Toyota Yaris car (2012).
9. Successful participation in the robotics competition in Vienna (2013).
10. Construction of a dual system: autonomous car + autonomous drone to participate in the Valeo program (Paris 2013).
11. Participation in the inauguration of the European Rover Challenge together with Prof. Howard Scott (NASA, Stanford University) and Dr. Robert Zubrin, founder of the "Mars Society" (Kielce 5-7.09.2014).
12. Pipeline inspection robot (2017).
13. Robot for qualitative testing of surfaces in construction (2017).
14. Since 2019, cooperation with SatRevolution in the field of satellite constellation and robotics in space.
15. Publishing a book on robotic hospitals of the future entitled "Hospital 4.0" based on conferences organized in 2016-2020 (Wrocław University of Science and Technology, 2020).
16. Presentation at the International Astronautical Congress in Dubai of development concepts for autonomous robotics on Mars and the Moon (2020, 2021).

In parallel, for over 20 years, topics directly related to school robotics were developed, transferring knowledge to schools, first in Wrocław and later throughout Poland.

17. Developing interest in robotics in your own children, starting from kindergarten and ending with higher education (from the beginning of the 21st century).
18. Developing students' interests in the specially established Inter-Faculty Scientific Club of Vehicles and Mobile Robots (KNPiRM) at the Faculty of Mechanical Engineering of the Wrocław University of Science and Technology (abbreviated name LEM – Light Electric Motorcycle, from the beginning of the 21st century).
19. Participation in the first robotics competition in Lower Silesia, "Polish Championships of Robot Models and Rescue Units" (Rob-Rat), organized by the Nicolaus Copernicus Youth Cultural Center



***6**. Instytut Inwentyki*

***7**. Instytut Inwentyki*

in Wrocław (2003).
20. Creation of over 30 robotics clubs in cooperation with the City Hall in Wrocław schools (2010).
21. Organizing the first "Robot League" in Poland, as above (2011-2014).
22. Organisation of the 1st Polish Robot Championships (Wrocław 2012).
23. Participation in the program "From a small school into the big world" - 119 schools, 641 teachers, 8343 participants throughout Poland (2010-2013).
24. Establishment of over 40 robotics clubs across the country by 2018.
25. Organizing the first conference on teaching robotics in primary and secondary schools at the LZN in Wrocław (2018).
26. Reactivation of the "Robotics in Lower Silesian schools" program after the pandemic (Legnica 18/06/2021).
27. Strategic study of the Inwentyki Institute entitled "School Robotics in Poland" (28/07/2021).
28. Launch of the "Laboratories of the Future" program by the Ministry of Education and Science, over PLN 1 billion for primary schools throughout the country (from September 15, 2021).
29. Conferences on school robotics organized jointly with the Lower Silesian Teacher Training Center in Wrocław (15/11/2021; 21/06/2022; 20/10/2022; 15/12/2022).
30. Regional conferences organized jointly with the Lower Silesian Education Superintendent (August 2022), during which information was provided about the "Robotics in Lower Silesian schools" program (Wrocław, Legnica, Wałbrzych, Jelenia Góra).
31. Conducting a cooperation survey among Lower Silesian schools (August 2022).
32. Creation of a list of schools participating in the program (November 2022).
33. Formation of the Leadership Team of the "Robotics in Lower Silesian Schools" program (15/12/2022).
34. Appointment of the Team of Experts for the "Robotics in Lower Silesian Schools" program (15/12/2022).
35. Presentation of curricula for primary schools in the field of school robotics (31/01/2023).
36. Presentation of the action plan for 2023 (31/01/2023).
37. Organizing the Polish Robot Championships under the patronage of KGHM (Wrocław – 01.06.2023, Legnica 19.06.2023).
38. Organizing the Polish Robot Championships with the participation of the Marshal's Office of the Lower Silesian Voivodeship, universities, the National Committee for Space Technologies, NOT and students, as well as primary school pupils (Wrocław – Legnica, October 2025).

3.3. Space robotics [9]

Space robotics projects were developed after the COVID pandemic in 2022 and launched in Legnica for the first time during the Polish Robotics Championships in 2023. The robotics competition was organized under the patronage of the Prime Minister of the Republic of Poland with financial support from Lower Silesia's largest company, KGHM. Below are sample photos from the event, as well as selected works by primary school students.

In 2024, no support was received and the project was not launched. In 2025, the Polish Robotics Championships, held in Wrocław and Legnica, included competitions on space projects. They were organized with the support of the Marshal's Office of the Lower Silesian Voivodeship, the National Committee for Space Technologies, and with the participation of NOT Wrocław and NOT Legnica. The following photos show selected student projects.

3.4. The "Key to Space" Program

In 2025, the POLSA project was launched, aimed at primary and secondary school students aged 12 and over. The kit includes an instructional video, assembly instructions, basic soldering exercises, lesson plans, and 3D projects. The program launched on November 7, 2025. There is currently no information on the project's practical results.

This article does not discuss the "Rover Challenge" competition for students of higher education institutions, hoping that the topic will be presented by the organizers also in the pages of this "Przegląd Komunikacyjny", as it is worth popularizing this success not only in Poland.

4. Conclusions

Direct conclusions from the Polish Robot Championships 2025

- Both the Wrocław and Legnica centers have been national pioneers and natural sites for the development of school robotics, including space robotics, for many years and should continue to be utilized to expand this field. These centers offer excellent conditions and are well-equipped to provide the necessary staff. The gathered robotics enthusiasts are also capable of developing principles that will ensure the development of this area of education [10].
- Robotics topics, which have already reached primary schools on a relatively large scale, should be continued.
- Consider incorporating military/war robots into future robotics competitions.
- Collaboration with NOT Wrocław and NOT Legnica, as well as with universities, should be continued and expanded. NOT structures across the country could be utilized for this purpose.
- The robotics program should cover kindergartens, primary schools and secondary schools and

should become a permanent part of the support program for Marshal Offices across the country.
- Additional remuneration or special rewards should be provided for committed youth caregivers.
- Lower Silesia, as a major industrial center, should develop the proposed forms of activity, which will facilitate the region's high-level economic development in the near future. The ideas and initiatives born in Lower Silesia should be transferred through the KKTK throughout the country.

Conclusions of a general nature

Economic development and the future of societies rely heavily on technological advancement, as has been evident for many years in Silicon Valley and increasingly in the Far East. This is based on the introduction of STEAM and TED disciplines into teaching practices at the earliest possible stage. AI has been added to this mix over the past three years, as pioneers around the world have already discovered. The enormous funds spent on "Laboratories of the Future" have provided primary schools with appropriate equipment, including robotics kits and 3D printers, which are currently underutilized.

This is influenced by the overall situation in the education system, as evidenced by the basic data presented in the latest TIEMS report. In Poland, the education system is short of 15,000 to 30,000 teachers. Tens of thousands of people leave the profession every year. In 2024, this number reached 20,000. Nearly half of those with less than five years of experience are considering a career change. Teachers are the most burnt-out professional group. Only 30% declare job satisfaction. In Finland, it's 92%, and in Norway, 88%. Poland currently has the oldest teaching staff in Europe, which hinders the introduction of innovation. The authorities are preoccupied with ideological issues instead of solving problems related to technological development. Poland is heading towards an educational disaster, as was heard at numerous conferences (ECC Katowice, Forum G2 in Wrocław). The recent changes to the core curriculum are generating a lot of unnecessary emotions, therefore, the positivist efforts of our team should be fully supported. We must continue to act and do our part. Based on the experience of MPR 2025, we have decided to organize the Polish Secondary School Robotics Championships again. Initial arrangements have been made with the Aviation Research Institute and SIMP NOT in Wrocław. We must continue to foster educational development in our region, and our example will undoubtedly be followed by others, as these are inevitable global development trends.

In an effort to accelerate the development of the space industry, it is also proposed to promote the idea of academic and school entrepreneurship among students and pupils. As in the past in the IT field, start-ups in the space industry should be established at the educational level, in accordance with Polish law , starting at the age of 16. To this end, among other things, Space Science Clubs should be established in secondary schools. School Science Clubs should be organized as the best clubs at universities in the automotive industry, operating like industrial companies.

Due to the scarcity of specialist academic staff at universities, consideration should be given to having classes taught by staff from several universities in order to cover the entire spectrum of issues at the highest possible level. Cooperation is essential.

In this way, space education will encompass all levels of education simultaneously. Poland will once again be able to achieve success, similarly to its IT sector, bringing us closer to our goal of becoming the 15th-largest economy in the world.

This appeal is addressed to all our readers, space enthusiasts, members of the National Committee for Space Technology, teachers, students, and pupils. NOT - the Chief Technical Organization, also known as the Independent Technical Organization. Regardless of views, past, gender, or political affiliation, we propose tomorrow's solutions today for all interested parties.

If you would like to cooperate, please contact us directly. ◀

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National Committee for Space Technologies

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- Space technologies
- National and international cooperation
- Applications and commercialization
- Civil and military areas
- Cooperation between science, business, central and local authorities
- Universities, Polish Academy of Sciences units, Łukasiewicz Network, schools of various levels
- Partner organizations in the fields of aviation, telecommunications, medicine, agriculture, etc.
- Golden rules of space safety

Krajowy Komitet ds. Technologii Kosmicznych

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- Technologie kosmiczne
- Współpraca krajowa i międzynarodowa
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- Obszar cywilny i wojskowy
- Współpraca nauki, biznesu, władz centralnych i lokalnych
- Uczelnie, jednostki PAN, Sieć Łukasiewicza, szkoły różnych szczebli
- Organizacje partnerskie z obszaru lotnictwa, telekomunikacji, medycyny, rolnictwa itp.
- Złote zasady bezpieczeństwa kosmicznego