INTL JOURNAL OF ELECTRONICS AND TELECOMMUNICATIONS, 2025, VOL. 71, NO. 3, PP. 1-9
Manuscript received May 23, 2025; revised July 2025. doi: 10.24425/ijet.2025.153628

Space 4.0 – a common, democratic European space, part 5

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***Abstract*—Space 4.0 is a complex infrastructural, but also sociological process and political ideology, which we tried to present in the local context from various sides. Space 4.0 turned out too complex to show all its dynamically changing attributes. Space 4.0 is realized in complex economic and political environment even in the EU. Some of these issues are related to the existence of technological and economic boundaries in our region and particular political interests. Space 4.0 major goal is to build a democratic European space in real existing economic conditions, not theoretically, and in in the nearest future. Our intention was to present the image of the European space sector in an optimistic way, but simultaneously we did not omit some critical reflections. The great idea of Space 4.0 should not be reduced only to a technical and simple business layer connecting the LEO zone to the Industry 4.0 economy. Space 4.0 contains also space based services. Space 4.0 is not only a simple ecosystem of small and cheap satellites. It is much more than this. We are proud participants of the Space 4.0, learning from mistakes, encouraging SMEs to be active, undertaking important administrative initiatives, to build real new, active societal space sector.**

***Keywords*—space policies; Space 4.0 project; European Space Agency; space democratization; space and satellite engineering**

I. Introduction

THE Space 4.0 is undoubtedly part of the Fourth Industrial Revolution 4IR, referred frequently to as Industry 4.0 [12]. Space 4.0 has turned currently to global phenomenon, after only a decade of formulating and beginning the implementation of the idea of economic opening of near outer space on new common principles. Its scope includes not only all interested areas, countries and organizations, but also entities from the largest government agencies, key companies in the space sector, massively emerging start-ups and spin-offs, sectoral research institutes and university laboratories, as well as investment capital. This global, multi-layered, economic and social phenomenon inspires and initiates many new economic, industrial, managerial, political and cultural processes. Space 4.0 is evolving very quickly, decisively and irreversibly, from a relatively simple initial technological and economic - service approach towards a true opening of space for our entire civilization. It had to happen sometime.

II. Space 4.0 – the most important first decade 2016 - 2025

The Green Deal Industry Plan, concerning the leading role of European industry with net zero emissions, is the only such global strategy developed and implemented comprehensively in Europe. It is inherently connected with the Industry 4.0. Various parts of such a plan are also implemented in other economic super-regions, but in no such comprehensive way. Potentially, the European energy transformations and the green deal also concern space technologies and therefore also Space 4.0. In all space super-regions, the idea is to make the use of materials, energy, workload, costs more efficient, when building ground and orbital infrastructures. In the dominant American and Chinese regions, there are no internal borders, economic dynamics and central decision-making changes are carried out completely differently than in the European region, where, despite the union, quite strong borders exist. These borders are also reflected in the technological development of Europe, including the space sector and its several functional layers that differ from each other.

The first decade of Space 4.0 development could not be spoiled. It is an initiative that is too massive and too attractive. It is an initiative of global social liberation and economic opening of space from government monopoly. It seems that this liberation took place quite late, mainly under the influence of strong social, but also political and economic pressures. The first timid small satellites had dimensions a multiple of 10x10 cm, today the famous CubeSat standard. CubeSats contributed to a large extent to strengthening the process of opening up the space. We are talking about the decade of the EC Space 4.0 initiative announced in 2016, but it has matured earlier [1]. The benefits of a wider opening of science, technology, economy and services to space were constantly being talked about in the European economic and political spheres. Such opening became all the more compulsory because economic space started to open up earlier in the USA and China.

However, the breakthrough could not happen in an instant. From the very beginning of the launch, it was realized that the space sector imposes slightly different, much more difficult requirements on the planned satellite business implemented on small satellites than many, even technologically advanced, terrestrial sectors. The exclusion of direct servicing of orbital equipment due to costs required a complete switch to remote servicing. It became necessary to develop, almost from the beginning, full business models of ecosystems supporting Space 4.0 technologies [2]. This almost from the beginning, however, meant significant use of experience from conducting space projects in the period preceding Space 4.0 and early tests. In particular, Space 4.0 scientific and utility orbital equipment is developed much faster and using commercial components, but maintaining a multi-stage, standardized preparation and testing

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process [3], [4].

The development of Space 4.0 in the first decade is driven by many factors such as: very favorable predictions of the development of innovative and business open space sector [5] and surprising development of the directions of these predictions in the years 2020-2025 [21], [22], [23], strong synergy with other major transformation processes of economic changes taking place, such as the digitalization of everything [6], the use of small cheap satellites but also with the possibility of building mega-constellations [7], [8], potentially competition and globalization [9], synergy with the ongoing fourth industrial revolution 4IR Industry 4.0 [10], [12], [16], the construction of manufacturing plants in space in the future [17], significantly increased possibilities of preparing new precise simulation solutions of small satellites in virtual space and rapid prototyping methods [11], in some cases easy scaling down of small satellite drives [13], the development of reliable, intelligent power sources [14], artificial intelligence and advanced software for autonomous constellations of small satellites [15], application of robotics, digital twin technology [18] and additive manufacturing in intelligent production of small satellites [25], application of new AI tools, ML, expert systems, immersive reality and methods of conducting Space 4.0 projects, such as KBES, MBSE, RCPSP [2], [19], [20].

Space 4.0 is also developing in Poland at an excellent pace commensurate with the processes taking place in most technologically motivated regions of Europe [24], [26]. Space 4.0 in synergy with the domestic 4IR industry, electro mobility, renewable energy sources, the emerging quantum sector of the economy, security, defense and cybersecurity, and other technological innovation sectors is an opportunity for Poland to quickly enter the exclusive group of leading economies of Europe.

III. Space 4.0 – is it different from OpenSpace in other Space Super Regions?

The fundamental difference of the European region, apart from the existence of national borders and particular national interests, is the lack of an appropriately strong economic and political central unit coordinating joint activities in the space area, including the Space 4.0 sector. Let us recall that ESA is a very important coordinating unit, but rather only the research and research-industrial sector, and certainly much less or not at all applies to Space 4.0 and developing new space oriented services. This is too little to represent and coordinate the entire European industry. Another feature of the European region is the issue of only a gentleman's, not a hard, division of space competences between the EC and ESA. Such a situation does not facilitate making global decisions regarding the space sector in Europe at a level comparable to decisions made in the American and Chinese regions, or even in India. So how does Space 4.0 differ from OpenSpace in other competing space regions, and what are the consequences?

The global, positive idea of an economically and socially OpenSpace/NewSpace, the general European idea and program Space 4.0 currently dominates our part of the world. We are slowly approaching its implementation during the first decade. This local dominance concerns two layers, ideological and practical, i.e. an increasingly broader social change in the understanding of near space as our area of necessary economic and civilizational maturing, and practical, functional economic development. The ideological layer is the evolution towards a space society, culture, eternal striving for expansion, travel, knowledge, looking from the outside at the cradle of life on Earth. The ideological layer is also a certain enthusiasm visible in Europe regarding new directions of development and their potential.

Reasonable enthusiasm is always surrounded by reflection, different at the highest managerial level and different at the lowest executive level. Similar questions keep coming up, whether we will cope with global competition, whether the game will be fair, whether we will be able to level the playing field in our European space region, whether our legalization guidelines will find global recognition, whether the entire sector will not be dominated by ideologies, what is the real scale of our European space enthusiasm in the face of other more important matters, what is our willingness to learn and innovate, what is our perseverance in building a space culture at all levels of the society?

Despite its difficulty, the practical layer, given the above-mentioned ideological, social and cultural problems, seems relatively simple. Nothing could be further from the truth. Some experts claim that for now we are effectively managing to litter the Earth's immediate surroundings with tons of equipment that is not sufficiently effective functionally. Maybe this is the price of learning and the quite recent beginning of the massive popularization of space technology, starting from its simplest levels. The practical layer is technology, orbital and planetary infrastructure, expansion of the economic area, industrialization, services, searching for and generating new functionalities. In this search for practicality and beneficial utility, we are still at the beginning. Space 4.0 is to be an idea close to us, society and almost an individual, culture and economy, bringing effects almost immediately on a scale of individual years, but also planned far in advance. We had to mature to such an idea both socially and technologically. It probably could not have appeared much earlier. Before, there were only large, quite strictly closed projects. Outer space was appropriated by governments. And even before that, there were only dreams. On the practical level, it is about converting dreams into a wide range of functionalities based on effective infrastructure platforms - hardware and software.

The OpenSpace effect in various space giga-regions and also Space 4.0 in Europe is astonishing. A completely new area of industry is emerging. Tens of thousands of small satellites are already being produced annually. Orbital infrastructure is growing at a rate of tens of thousands of tons of increasingly advanced equipment annually. The two leaders, the USA and China, are beyond the reach of any other competition. Somewhere behind them, Europe, India and other regions with space ambitions that can afford it are developing their space areas of ambition and competence. In these mentioned areas, the idea of OpenSpace is understood differently by the leaders, despite a strong common denominator in the form of the social and economic opening of near space. OpenSpace is currently, in one sentence, in practical terms a massive, almost avalanche-

like industrialization of near space, but in the emerging broader social context.

The dominance of the industrialization and technical-competitive layer of OpenSpace in other regions is significant over other layers, including the socio-cultural one. It seems that Space 4.0 is a typically European approach, combined, ideological, economic and cultural, containing social components everywhere, including, for example, the green deal even in relation to outer space. Let us hope that this social approach will prove positive in conditions not only of fierce global competition. The social approach means fair, equalizing opportunities, engaging in progress and opening wider European areas to outer space, accelerating the pace and at the same time not creating sub-areas of different speeds, speaking in a different voice, surrounded by borders for fear of economic, technological, legislative domination of the stronger. The task is not impossible to accomplish but very difficult, as evidenced by the situation in other sectors of European politics and economy. Space 4.0 is a great opportunity for Europe to take on such a difficult challenge as effectively equalizing opportunities in its region, activating areas and increasing competitiveness.

IV. SPACE 4.0 – CHALLENGES AND POSSIBILITIES, LIMITATIONS AND OPPORTUNITIES

Neither OpenSpace nor Space 4.0 encompass the entire domain of cosmic knowledge and development. These processes encompass the closest, easiest to master, and currently the only space that is possible for rapid, even mass industrialization. The dynamic industrialization of space that we are witnessing, in an aggressive style more like OpenSpace than Space 4.0, but as far as possible in accordance with the assumptions of Industry 4.0, has different scales. At one extreme, these are planned on a grand scale and quickly implemented multi-billion projects with global reach and a large mass of equipment systematically and continuously orbited in order to create very massive, highly standardized infrastructures. At this extreme, only two leaders compete. The second, very interesting extreme of orbiting and creating functional infrastructure is small industrialization with significant diversity. It seems that this is currently the main area, but also a chance for the future, for Space 4.0 to operate.

In 2010, the main obstacle to the diversification of near-space research paths, in potential connection with its commercialization, was the very high costs of orbiting infrastructure. Also, the technology and orbital infrastructure, as well as the philosophy of its construction were different than today [1]. OpenSpace, and Space 4.0, which emerged a few years later, were primarily intended to investigate the possibility of making a significant breakthrough in this area. It was already known then that the path in this direction was opened by standardized small satellites built from standard commercial components. There were still a few missing key things to do. It was necessary to free space from the monopoly of space agencies, government giants cooperating only with the largest companies, and to reevaluate the understanding of such concepts as space security, open industrialization and commercialization, and wide usability and social access to near space.

It is amazing that most of these processes took place, almost on a global scale, in just one decade [4], [22]. This avalanche of transformation matured slowly much longer, for many decades. Along the way of these changes, successive smaller and larger obstacles, social, economic and technical, were overcome. Some time still has to pass, in many places technology does not live up to the dreams and practical needs of industrialization, we have to become much more familiar with space to fully feel that we are a space civilization. Perhaps we need to deeply understand that without mastering space we are a finite civilization, without a distant future. Only space will drive such directions of our future efforts that we would never have undertaken if not for its infinity. Space 4.0 has its fundamental place in these processes. Space 4.0 is not only the fastest possible orbiting of everything we have and that is suitable. This is, above all, a significant pressure for development, testing, innovation, and thus evolutionary building of lasting infrastructures and ecosystems, first changing the economy locally and increasingly broadly, and then culture and society. This is the potential of Space 4.0 and the opportunity for Europe.

The industrialization of space that we are talking about in various aspects, within the framework of the OpenSpace, NewSpace and Space 4.0 ideas, includes many new components that have not been discussed before. It also includes classical components that have been present in space research and exploration since the beginning of our space era. OpenSpace affects society on a global scale, completely differently than the previous OldSpace. OpenSpace and Space 4.0 require the development of a new legal framework. This will be a general framework, something like the Global Space Law, which has been in the works for a long time, acceptable to the global community, and a local framework that is binding in individual space super-regions, American, Chinese, European, Indian, Russian and others. Local laws regarding the space surrounding us all have limited meaning.

Space is not an area where you can set boundaries of influence like on the jealously divided Earth and define such boundaries through legislation. However, it is doubtful that it will be possible to quickly develop a common legal platform, just as it is difficult in the case of other areas, e.g. environmental protection, which reaches the regional level on Earth. There is no regional level in space. Even the nearest LEO area cannot be divided by borders. This will be a long-term effort, which is necessary and, let us hope, has the chance to develop some general common space legal principles at the beginning. Then, let us hope again, it will be a platform for further, more detailed legislative activities. On Earth, we have many such areas that are difficult to reach a global agreement on legislation. In addition to environmental protection on a global scale, we can immediately mention a memorandum on the development of artificial intelligence, genetic research, etc. Space 4.0 and OpenSpace in other regions will probably be conducive to starting a broader discussion on this topic.

Such major problems and the numerous details related to them are currently emerging before our eyes. The consequences of many of them are unknown to us, we do not understand them precisely. They must be settled in the system of our pre-space civilization so that they can be properly covered by a reliable legal framework. However, some current problems are known

in more detail and even require relatively urgent regulations. These problems have their consequences regarding the directions of development of Space 4.0 and OpenSpace class systems. They cannot be ignored. The occupancy of the LEO area is increasing exponentially. The amount of space debris is increasing in these areas. Larger objects from this area should be systematically and orderly deorbited, which is currently not generally solved systematically. Some operators orbit LEO equipment that is not internationally indexed. Some LEO satellites send sub-satellites in their vicinity, sometimes also not indexed. It is difficult to call this orbital space piracy, because there are no general legal regulations in this regard, only rather poorly functioning gentlemen's agreements, especially in conditions of increasing competition. Additionally, such satellites are sent by government agencies, so who will stop them?

The further increase in the number of LEO satellites will cause an increase in the constant illumination of the night sky, which is sometimes called cosmic light smog, which will probably be important for plant vegetation on Earth. We need to think about LEO satellites that do not reflect light. The technology of such completely dark satellites is not obvious. All these issues require research and significant innovations. Space 4.0 and OpenSpace have significant potential to strongly accelerate these required development processes. The delight that Space 4.0 will only quickly expand the range of cheap space services is of course true, but only in a very limited marketing and commercial sense. The potential of Space 4.0 is much broader, we just need to start using it effectively.

The hot topic of space legislative discussions is precisely the area of low LEO orbits. In no case would we like this area to become a modern space Wild West. For now, things are moving in that direction. The LEO area is already quite densely littered and this littering is still progressing quite chaotically. The rapidly increasing occupation of LEO space requires precise regulations, binding all operators of orbital infrastructures, regarding space traffic law. The law must regulate the principles of infrastructure operation and its removal. Space debris is already becoming an increasing problem because it was not possible to establish a common law regarding its generation and responsibility for its removal.

We repeat earthly mistakes. Let's repeat it once again, unfortunately in the LEO area we are quite close to the Wild West. In the further MEO and GEO areas space legislation must also act. In these further areas interest is aroused by gravitational characteristic points, which are increasingly densely occupied by satellite infrastructure. The rules of location and orbital movement near the Earth must be ordered and established. An example of a good agreement, but much easier to achieve, is space telecommunications law.

Will the situation of the space industry in Europe deteriorate significantly as a result of recent political and economic phenomena in the world? These phenomena are so massive and so surprising that they cannot be ignored. The Space 4.0 space sector is quite closely linked to other innovative technical areas covered by the principles of Industry 4.0. Significant changes are being observed, e.g. in the electromobility sector, energy, advanced manufacturing industries, free transfer of technology and knowledge, etc. In Europe, the SME sector seems to be strong enough to survive the current turbulence and new challenges. In Poland, the SME space sector is rather at the beginning of building its strength. The solution in the country may be to escape forward through the bold implementation of a modern scientific-production-development hub.

The aim of such a national space technology centre would be to create a market entity with headquarters in Poland, perhaps together with a global partner. Poland is a mass supplier of advanced technical components for various innovative sectors of the European economy. This is a strong basis for joining these experiences and skills of the Space 4.0 space sector of small satellites. The condition for development is that new companies and production plants for components for space technologies and integrators of small satellites will be established in our country. The foundation is the development of our own competences in the areas of Space 4.0 space technologies, including tele informatics, satellite mechanics and robotics, automation, standardization, reliability, innovative engineering and system integration, satellite energy, rapid prototyping and innovation. Not all niches will be filled by technological giants in the rich area of Space 4.0. In conditions of such concentration of effort, the national hub of space technologies can relatively quickly develop its own and full ecosystem of orbiting and maintaining small satellite infrastructures.

V. SPACE 4.0 – THE SITUATION OF SPACE INDUSTRY IN EUROPE AND POLAND?

The industrialization of near space according to the idea of Space 4.0, especially in the first stage of building satellite infrastructure for new and expanded services, does not require excessive presence of people on site in the organizational processes of orbital areas. It does not require direct participation of people at all. However, the problem of potential safety of people operating in orbit for research, service, technical, tourist and other purposes will always remain open. Space 4.0 is oriented, like Industry 4.0 in factories, towards robotization of orbital tasks. The margin of human participation must always be taken into account, especially in the later stages of implementation of more advanced open space technologies.

Space 4.0 is, where needed, a high level of robotization both in the navigation layer, positioning and stabilization of movement, collision avoidance in dense LEO space, but also automation and robotization of on-board satellite functionalities. The specificity of Space 4.0 orbital technologies is the limited life of a small functional satellite, low costs, maintenance-free functionalities, reliability and costs optimized for the planned life time, automatic self-elimination of equipment after its life in a way that minimally disrupts the operations of other and neighboring infrastructures, etc. Each orbital infrastructure, small and large, requires remote servicing and management after its life. The methods of removing infrastructure components depend on its orbital location. Such cleaning must be performed differently for LEO orbits and differently for GEO. The industrialization of near space is inextricably linked to the problem of various types of pollution, and protection of the Earth's natural environment, not only orbital spaces. This problem will grow and is indispensable with

the development of the massiveness of orbital infrastructures. This is also an area of Space 4.0.

Space 4.0 is a fundamental and usually multiple reduction in the costs of orbiting an individual small satellite and entire constellations of such satellites, a significant reduction in the dimensions and weight of satellites while significantly increasing their functionality, the use of standard commercial components. It also includes other solutions for orbiting nodes and the entire orbiting infrastructure, including launch systems, propulsion, navigation, traffic stabilization, communication within the constellation and with ground stations. As the size of the constellation increases to hundreds and thousands of small satellites, and orbiting costs are minimized, the issue of integrating as many satellites as possible into the payload of the launch vehicle arises. Depending on the functionality of the satellite, various methods of payload optimization are used, including standardization of dimensions, flat configurations of satellites for the time of launch into orbit, etc. Such extensive constellations cannot be launched in one or even several orbital missions. The ability to precisely arrange and synchronize the operation of the full constellation into a functional whole is necessary. This is a completely new skill that is being acquired, completely different from coordinating orbital movement and the functionality of just a few satellites. This is also, in a sense, a result of Space 4.0.

The reduction of space technology costs has many aspects. In general, we can say that Space 4.0 is a new low-cost and mass space technology. It includes not only satellite skeletons, structural and functional modularity, standardization, orientation, stabilization, propulsion, and many other technologies of small satellites. An element of Space 4.0 is the step-by-step effective implementation of technological innovations developed in small and medium-sized private industry, and the stimulation of the development of mass production of such industry. This is what is happening. In many European countries, the development of the manufacturing SME sector is progressing very effectively and will soon be much more strongly reflected in LEO orbits.

For now, we are observing the activities of pioneers and the testing of small satellite orbits by the SME space sector. This sector uses orbits offered by large companies, but this will not always be the case. After some time, with such an intensive pace of development of Space 4.0, the SME sector will organize itself to create common integrated infrastructures creating a full functional ecosystem. It is worth emphasizing that the separation of small industrialization from the construction of large ground and orbital infrastructures is related to the interest in the idea of open space by small, large and very large players. Such small and very large orbital infrastructures have completely different characteristics. It is as if two poles of the same planet. And everything is happening within the same Space 4.0. Space 4.0 was supposed to concern small, and due to its revolutionary approach to the industrialization of space, it concerns everyone.

Space 4.0 is hardware but also innovative software, prepared completely differently than in the era of space unavailable to the public several decades ago, and even differently than just a decade ago. Space 4.0 cannot avoid intensive interaction with the developing era of machine learning, implementation of orbital self-repairing equipment and Artificial Intelligence. The idea of Space 4.0 will replace simple small satellites not equipped with advanced functional intelligence systems. Despite the reduction in the costs of building orbital infrastructures using small satellites, they are still so significant that equipping such infrastructures with intelligence does not fundamentally change these costs, but potentially adds significant possibilities for expanding and optimizing functionality. Who would want to give up such an optional and almost cost-free option? We have mentioned it previously that the measure of the presence of the Earth's super-space region in orbit will not be so much the number of satellites or their mass, but the quantity, diversity and quality of orbiting intelligence. The remaining parameters will become derivative. Satellite mass will remain a fundamental factor in large research applications, in large missions, and in the area of security and defense.

The service, commercial and research paths of open space are fundamentally different from each other, which is reflected in Space 4.0. Let us try to briefly characterize the research branch of Space 4.0 and look at how it may differ from the service one. In the common understanding, the idea of Space 4.0 is related to the universal commercialization of space on a larger and smaller scale, as well as a very small one, but as it turns out, also very large. Space 4.0 also affects the space research sector. With such a massive change in satellite technologies and the approach to designing, building, testing and massive orbiting of equipment, the research sector is subject to wide influences of these changes. However, the space research sector is different from the commercial sector of Space 4.0. The commercial sector will become increasingly standardized on a mass scale in terms of hardware and software. The research sector, despite undergoing processes of transformation and differentiation between experiments of different sizes, will remain unique in the layer of specialization of orbital and off-orbit measurement equipment.

Reducing the size of individual experiments, increasing their variety and the frequency of sending research missions into space already has consequences for planning and designing research experiments. The main research trend cannot and probably should not change as quickly as the commercial one. The definitions and functional consequences of the reliability of space infrastructure are different in both trends. In the commercial sector, the aim is standardization and thus lowering costs. Differentiation of services is based mainly on the specialization of the software supporting it. In the research sector, the aim is the uniqueness of the research and most often individual solutions of the satellite on-board equipment. Some types of such on-board equipment used may be more expensive than the entire satellite carrying it.

The Space 4.0 research sector will remain much more expensive than the commercial one. Who bears the risk of these higher costs? Commercial risk is of a completely different nature. Will it be some new central European organization, or ESA, or will the risk be calculated into specific research projects, but differently in pan-European, international projects, and differently in national ones. In the situation of Poland, a

country intensively building its SmalSat sector, from a level different than European advanced space countries, the problem of insuring risky own research missions prepared by SME is unsolved. There are few of these missions for now and any event related to risk may delay the development of the entire sector for some time. Small-scale, own, orbital research missions must be carried out in Poland in order to obtain and develop competences and a certain degree of technological sovereignty. Such missions are much more than the interest of a specific Space 4.0 sector company developing in the country. We call them research here, but in principle they are scientific and technical test missions. They are to check in the last orbital phase (of course after a comprehensive laboratory test) all hardware components that cannot be checked otherwise than in LEO.

As a country, we are in the period of building the foundations of our own space competences. The fragment of the SmalSat sector, especially concerning the construction of technological sovereignty, should be somehow protected by the state. This problem was clearly visible in the case of the small Eagle Eye satellite and it is not known whether it will not be repeated. Cooperation within the European framework allows us to build our own competences in satellite technologies faster. At the same time, such cooperation can make us dangerously lazy, as it sometimes happened in other sectors of high technology, and leave us at the stage of purchasing ready-made solutions, licensing development, building unnecessary dependencies, etc. The construction and continuous development of our own competences in Space 4.0 space technologies must be inextricably and absolutely connected with a certain margin of technological sovereignty. This connection cannot be achieved only and exclusively at the scientific-technical and innovative-industrial level. At least partial state care must be guaranteed. Such state care, for selected innovative technologies, does not constitute a conflict with activities in a common friendly European area. It is a beneficial, and on a different level, securing critical own interests.

The great experiment of friendly and open European cooperation on all levels of building a modern knowledge society is still a very difficult experiment conducted on such a scale and at such a level of advancement of social development for the first time in the history of humanity. Most of us probably hope that on the highest civilization platform we will succeed in releasing significant reserves of synergy and revealing further directions of development, which we see today in a haze. We will succeed if we solve together the main sectoral problems in the areas of infrastructure, social life, law, culture, development, security, but also critical detailed problems. We will succeed if we truly understand in a fundamental way that such a structure must remain a fair federation and not a super-state with a very strong center and peripheries. In the area of advanced technologies, which include the Industry 4.0 and Space 4.0 sectors, this means the most even development possible of the entire area of Europe, in accordance with the expectations and ambitions of individual regions. This also probably means a paradigm shift from imposing and centralizing technological development in Europe towards even development.

VI. Space 4.0 – a New Branch of Industry or Development Towards a Space Civilization

Let us ask a few decisive questions concerning the development of various technologies, including space techniques, but not answering them directly, but trying to determine where we are in terms of technical civilization and what are our chances for further development and at what pace. If we integrated our efforts within global civilization on such problems as health, individual and social well-being, energy, transport, artificial intelligence, quantum technologies, universal familiarization with space, etc., would we be much further along than we are now? Observing the development of space technologies in the last decade alone, we can say that an evolutionary new branch of the economy is emerging, created by industry and services. The obvious chance is that in combination with other areas of the economy and culture, the space sector, but not only the modest spark of Space 4.0, can set the next direction for the development of civilization.

Space 4.0 is a spark that ignite a fire, a small stone that starts an avalanche. Civilization is not only the economy and other material components but also dreams and their hard, consistent realization. Dreams are also further travels and settlements, first on the Moon and Mars. The space sector, similarly to other sectors, asks itself whether we would already have a stabilized settlement on the Moon and then on Mars today, if efforts were coordinated on a much wider scale than they are now, if gigantic funds were not spent on senseless goals. The health sector asks itself whether cancers and other civilization diseases could be controlled with massive coordination of efforts on a global scale. The agriculture sector asks itself whether we should not have solved the food problem once and for all a long time ago. The energy sector asks itself whether the energy problem could not be solved relatively quickly with the help of difficult, but with excellent prospects, fusion energy. The information technology sector is asking itself and us whether equipping artificial intelligence with self-awareness and robotic executive attributes does not put us on the brink of disaster and the potential end of civilization. Or, on the contrary, will allow us to move more quickly to another, higher level of development as a cosmic civilization.

Space cannot be developed without advanced intelligence extending materially beyond human possibilities. This is how we are beginning to think quite practically under the influence of OpenSpace and Space 4.0. The key to further development and the beginning of building a space civilization is perhaps that we must share our intelligence with an infrastructure created by ourselves that is capable of receiving and functionally using this intelligence. We cannot be everywhere ourselves, we cannot personally control everything. Scientific and technical knowledge tells us that technological disasters of various kinds, also based on space and also on a global scale, do not necessarily require self-awareness of the technical infrastructure. We understand that space is a risk, not only because of its size, but because we must extend our intelligence as far as possible into its depths. And space, as an area that is very demanding technologically and that revalues our culture, will play a key role in all these processes. It will directly shape our intelligence. Space 4.0 and its next generations will promote these changes in intelligence.

The humanities sector stubbornly reminds us that individual and social well-being is not necessarily the engine of progress, but can rather directly lead to laziness, discouragement and stagnation. We have had examples in history. Curiosity and the drive for development, may they last, force us to equip technology with intelligence. This also applies to orbiting technology and equipping it with the greatest intelligence possible. Such growing intelligence will evolutionarily surround us more and more precisely from all sides, in spatial, temporal, energy, functional and other domains. Space 4.0 is an avalanche accelerator of the distribution of distributed intelligence in the area of LEO space closest to us.

Space 4.0, set in coordinates such as the above, takes on a different meaning. It is simply a relatively modest development trend of science, technology, economy and perhaps also slowly culture currently towards the near space. This momentary modesty results from the young age of this idea. It is hard to believe that space was closed, completely appropriated, and generally inaccessible to an open society so recently. Despite this current alleged modesty, Space 4.0, due to the dynamics of its development, dares us to add many different extensions to this idea very quickly. Located about one light second from Earth, or two seconds of total net latency, the Moon is potentially an excellent place to set up a massive routing telecommunications infrastructure illuminating the entire Earth. Even Mars does not look too bad in this respect. The total net latency there is just over 5 minutes. For some applications, this may potentially be acceptable. This signal proximity in both cases slightly changes our thinking about distance and the possibility of settlement and resource exploration. It also allows us to forget a bit about the physical distance in kilometers and travel time using our still rather imperfect space vehicles.

There is no doubt that we are very lucky, the Moon is really very close, and it is an excellent space sandbox for taking the first steps of settlement, construction and exploration, early testing of the extraction of valuable resources from the regolith. It is as if someone intentionally gave us this Moon so close so that one day, when we grow up, we would start experimenting with it seriously. Without the Moon it would be incomparably more difficult. It is a wonder that we are not there permanently yet. Through neglect, through laziness, through stupidity and divisions on Earth, or maybe through forgetting that it is still there even when we are not looking at it. It is impossible not to look at it, from every corner of the Earth it looks the same. It shines so brightly in its fullness, inviting, awaiting our visit as soon as possible. We hope that the opening of space, that Open Space and Space 4.0 will really change this soon. Our Moon is an open, first gate towards the space civilization. Our common OpenSpace must reach there.

VII. Space 4.0 – We are Repeating the Same Mistakes in Space that we Made on Earth

Let us assume for a moment the worst case, that this is unfortunately how it has to be. That we have to repeat some earthly mistakes. It seems that there is no way around it. Within the framework of the global OpenSpace idea, only certain agreements concerning the least critical areas are possible and beneficial. This certainly does not currently concern technological competition and the functional occupation of LEO space. This, in the case of an aggressive approach, does not seem to be negotiated at present. Do super-space regions politely ask other neighbors, or on a global scale, whether they can orbit their equipment? For now, this does not concern joint large research experiments on a global scale either. Such experiments involving all space giga-regions together are not planned. Experiments and projects are planned, where individual leaders are separate giga-regions and they try to influence the outside. Massive legislative projects concerning OpenSpace and having a global reach are not planned for now. However, giga-regions try to attract smaller players in as many numbers as possible by creating collective programs.

These considerations regarding global initiatives, or rather the lack thereof, could be continued for quite a long time. What does this mean for our Space 4.0 ideology? It marginalizes and belittles it, relegating it to the role of a local economic initiative. Can such a scenario work? In that case, let us ask the question whether it is possible to avoid making mistakes in space on Earth, and if so, what kind? Space reflects the economic and political situation on Earth and does not set a line that cannot be crossed for mistakes and particular interests leading to them.

Sometimes it even seems that in critical cases space can lead to deepening and strengthening differences in views and interests. Space is potentially a great field of global cooperation, but at the same time a gigantic, new, somewhat different from traditional, economic, cultural and political battlefield. OpenSpace and Space 4.0 open this battlefield wide. In the case of cooperation, it is an area offering unprecedented opportunities to generate additional value for the entire civilization through multi-layered and multi-dimensional feedback loops and synergies. In the case of aggressive competition, space is dangerous at a level we have not encountered before. We would not want the new gigantic possibilities opened up by OpenSpace and Space 4.0 to add to these threats already existing on Earth. And yet we are aware that there is a danger of adding another cosmic dimension to the threats. Our civilization, divided into quite strongly polarized space giga-regions, will have to choose between such poles, cooperation and synergy, fair competition, or predatory competition and aggression.

OpenSpace and Space 4.0 make us aware and open up a new kind of gold rush. They make us aware in a new way of the size of the space for exploration and development and indicate completely different possibilities if we act synergistically. Space 4.0 is a great, new opportunity for our European region. In our limited European region we should and can, must and it is our duty to try to avoid making many of the earthly mistakes. In Europe, achieving a space consensus can be much easier. Regardless of the European consensus and synergy in the country, we should not make the old mistakes of neglecting to develop the Space 4.0 sector in Poland. Space 4.0 technology includes almost everything that is related to innovation and development today. In the area of Space 4.0, it is about the broadest possible cooperation on the European and international technological market, but at the same time about developing in the country absolutely necessary independent, own technological competences of components, integration and ecosystems. Competence sovereignty in the area of advanced and innovative technologies is currently at the weight of the country's sovereignty.

Let's look again at Space 4.0 from the perspective of the competence sovereignty of Europe and Poland. Europe has nothing to fear in the area of technology, if only politics and management do not fail. It is obvious that we have something to

catch up on and it could be better. It is obvious that this competitiveness in Europe is unevenly distributed. We can observe the desire of leaders to maintain this unevenness to some extent. These may be mistakes, also in the space sector, which are not worth repeating. The future of European competitiveness on a global scale is boldly outlined in the Draghi report. It outlines simple, general, but strong development paths, which mainly concern technology, including the space sector. Space 4.0 can be a kind of new integrating development platform in Europe, if it somehow breaks through with the dominance regarding defense and security, and the green deal. Only in conditions of competence sovereignty in the area of innovative technologies can Poland contribute competently and creatively to such a platform in a way that is beneficial to the country and Europe.

VIII. Space 4.0 – Space Technologies, Resources and Competences, Development Paths, Business

Space 4.0 is analyzed from many sides in business terms, as a rapid evolution or change in the direction of development of the aviation and space sector, as well as a breakthrough technological revolution. It turned out from the very beginning that the classic business approach to Space 4.0 is not very useful. With a very wide range of actors, from very large to very small, it was impossible to predict even the paths of financial and product flows. All components of the sector are changing, such as the emergence of private participation, the participation of industry, universities, innovation laboratories, entangled with many processes, digitization, artificial intelligence, miniaturization, decentralization, new methods of partnership, and demographic changes [2]. Managing Space 4.0 projects requires a new approach, including the identification of critical success factors and individualizing a specific project. Space 4.0 contributes to replacing classic management methods in "terrestrial" sectors with more demanding space methods of system engineering based on the MBSE model (model based system engineering). MBSE is based on three pillars, language, tools and methodology and represents the product through the processes of specification, design, integration, operation and validation. MBSE is a standard method that is used by big players like ESA, NASA, CNES, Thales and others.

For fundamental reasons, mainly maintaining the quality of production processes, Space 4.0 had to be applied universally by all participants in the space opening processes, including the smallest ones. The MBSE process uses keywords such as: precision - consistency, correctness, completeness; tracking - previous decisions, problems, requirements and risks; reuse - alliterative creation of alternative solutions with reuse of components; information exchange - connections between management, engineering and technical models; knowledge capture - the model as a project memory. In other words, Space 4.0 is not a completely technological and organizational revolution from scratch, we are quite well prepared for it. This is good news for larger satellite players, for quite small ones it is a certain difficulty regarding the need for hard adaptation in their activities to space requirements, even if non-specialized components are used in products but are available immediately.

Let's take a closer look at our capabilities in space technology, especially in our country. Let's start by recalling a few trivial truths related to society's space ambitions. Do we have space ambitions? Will the Space 4.0 mechanism really work and will space be freed? Will the necessary control mechanisms not paralyze this opening and make it seem superficial? Some events on the domestic market of the currently rather modest space sector are causing concern. Society's space ambitions are a much broader issue than the excellent, useful, and recently formulated idea of Space 4.0. Building and maintaining an effective industrial space sector in the country requires the existence of components, similar to all areas of high technology.

Space technologies require the ability to integrate many disciplines of technical sciences, physics and chemistry, but also economics, politics and management, at the system and functional level. Space technologies include classical and precision mechanics, mechatronics, materials engineering, electronics and telecommunications, electrical engineering and energy, optics, optoelectronics and photonics, robotics and control, drives, stabilization and geo-orientation, metrology and telemetry, technical informatics and computer techniques, reliability and science and system techniques, and many others. Are we able and capable of combining so many areas into a whole that gives a functional product, e.g. in the form of advanced functional families of small satellites.

A society with space ambitions has adequate scientific institutions that constitute the basis and lasting foundation of such ambitions. In a sense, they are the most important, but they are not enough to build a full sector. A lasting scientific foundation is necessary to interface our efforts with the world, to learn about this world, to educate scientific and scientific-technical staff, and to build further structures of the local space sector on such a foundation. We have such a solid foundation in the country, including astronomy and astrophysics, radio astronomy, planetary geology, metrology, space research and satellite techniques. The significant human and material resources, laboratory, research and technical resources of the PAN CAMK and CBK institutes are complemented by several strong university units, also in the rank of faculties and institutes, scattered all over the country, in Łódź, Kraków, Warsaw, Wrocław, Gdańsk, Poznań, etc. Space 4.0 has enriched this sector with many small innovative and manufacturing companies. Some of these companies have managed to grow.

The foundation of space competences of society is in fact a complex structure with various components between which a certain kind of dynamic balance is essential. Generally and simplified, it is divided into scientific, administrative, research, development and innovation, industrial, implementation, applications and services. In the administrative area, there are central bodies, POLSA and other institutions that are equivalents of analogous international bodies. In the layer from R&D to implementation at the central level, there could possibly be one of the Łukasiewicz institutes. A certain fragment of the space sector is supported by ILot, but it is definitely too narrow to be considered sufficient. Another fragment of technology that can possibly be used in space is owned by the PIAP institute. There is no such separate institute in the Łukasiewicz network.

The development of Space 4.0 in Poland could start with sufficient acceleration from the beginning due to the existence of its own strong, although dispersed, scientific, but also R&D

and technological space competences in the country. These competences from several main sources have been replicated and positively dispersed almost all over the country. This process of building the sector is still ongoing. Space 4.0 is generating an increasingly strong private sector of SME spin-off, spin-out, start-up, fintech companies in the SmalSat sector have already managed to grow. Competencies are evolving from the level of building components, systems, subsystems to the design and construction of own small satellites with general communication and observation functionalities. National competences in the field of building components currently cover practically all the layers necessary to build functional small satellites. This bodes very well for the development of the Space 4.0 sector in the country. Orbiting of many small domestic functional satellites, of completely own design, are planned in the near future.

The assumptions of the government's 650 billion+ strategy regarding the technological and energy transformation of the country include a number of high-tech sectors such as electro mobility, cybersecurity, nuclear energy, potentially also areas of quantum technologies, Space 4.0 sector and others. In the case of Space 4.0, similarly to other key technological sectors, the idea is not to rely mainly on importing solutions. The space sector, which is to effectively contribute to the country's economic growth, requires the application of a long-term strategy in all component layers such as education and continuing education of engineering staff - also at the highest doctoral level, continuous development of research and development infrastructure, maintaining beneficial cooperation between the public and private sectors. Such a development scenario fits the government's transformation strategy of the country's economy.

The implementation of the scenario could, for example, be entrusted to the special purpose company SmallSat Poland - SSP, implementing the strategy in an appropriate public-private partnership PPP model. Such a solution could provide a good guarantee for the domestic space sector Space 4.0 and equip it with the appropriate force of action, not only on the domestic market by attracting VC companies, but also on the international market. Such a solution could initiate the creation of innovation centers, R&D units, producers of advanced technologies around the investment in SmallSat Poland, connected by local highly specialized supply chains. The SSP company should initiate and support the establishment of satellite technology production plants in the country for domestic use and export, including small satellites. The aim would be to create a strong national production and development hub for satellite technologies. The hub would become an area of continuous training of staff at a high level and a generator of new jobs in the region, as well as a co-investor and coordinator of other ventures in the area of high technologies throughout the country. Such a hub, combined with other planned technology centers, e.g. electro mobility, renewable energy sources, Polish Academy of Sciences and Łukasiewicz Institutes, etc., would have the potential to create a type of high-technology network with a strong impact on many key areas of the country’s economy.

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