Polish Space Agency

Polish Space Sector 2020. Analysis of the current state, trends and technologies in the national and international context

May 2021, Warsaw

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ISBN: 978-83-65997-55-5
POLSA_A/2021_01

Department of Strategy and International Cooperation
Polish Space Agency 2021

Summary

The space sector is one of the highly advanced and innovative areas, which is becoming increasingly important for the national and international economy. Entities of the Polish space sector have been developing their competences very dynamically for several years now. Therefore, there is a need for constant monitoring of technical and technological progress. This analysis is an attempt to determine the current state of development of organisations operating in the Polish space sector. The publication is addressed to scientific, industrial and public administration environment.

The first part presents synthetic information on the domestic sector, the breakdown into categories and areas and its conditions, together with the requirements that are set in the international context.

This was followed by a series of analyses and the presentation of data i.e.:

a. Currently, the Polish space sector consists of 331 entities, of which 79% are enterprises, while 21% are research and development centres and universities. 60% of industrial entities have the status of an SME, while the remaining 40% have the status of a large company. In addition, a significant proportion of entities 74% started their activities after 2001. In 2019 the employment level of the Polish space sector was about 11.6 thousand employees.
b. Within the framework of the Fast Track - Space Technologies financed from the National Centre for Research and Development (NCRD), funding was granted to 15 projects for a total amount of PLN 143.8 million; additionally, over 40 projects were financed under other NCRD programmes. On the other hand, in the period from 2015 to 2020, the National Science Centre financed more than 300 projects for a total amount of PLN 212 million.
c. Cooperation in the international arena, e.g. with the European Space Agency under the PLIIS programme, made it possible to co-finance 210 activities for a total of approximately EUR 65 million, which constituted 45% of the Polish mandatory contribution to ESA. Additionally, in the years 2015 - 2020, a total of over EUR 60 million was allocated for optional programmes and over EUR 50 million for mandatory programmes. On the other hand, during

the operation of Horizon 2020, 39 projects were co-financed for a total amount of EUR 12.75 million, thus Poland advanced to 12th position in the ranking in terms of the level of co-financing.

d. An analysis of the development of technology domains under the PLIIS programme has identified two domains in which the Polish space sector has most frequently developed its competences, i.e. TD6 On board Radio Communication Systems and TD2 Software for Space Systems, in which the sector's competences are at level 8 of TRL. However, we can conclude from the results of the survey that among our entities, as many as 11 technological domains were indicated as important.
e. The predominant group of products and services owned or developed by Polish entities concerns software and data processing as well as information systems for modelling and simulation.
f. Limited liability companies dominate among industrial entities of the sector, only 3 entities are joint-stock companies, while scientific entities include universities, universities of technology and institutes.

Another step was to perform doubled SWOT analyses, i.e.:

a. The first one focused on the Polish Space Strategy identified innovation potential of Polish companies as a strong point, which is undoubtedly influenced by the high level of education in the field of technical sciences. Additionally, Polish entities actively participate in space projects, e.g. ESA, which is reflected in the high degree of use of the membership fee dedicated to optional programmes. On the other hand, the weakness is related to the low level of state investment in the sector.
b. The second analysis concerned the ESA's study and report, and it allowed to identify several strengths of the Polish sector, e.g. possession of high competences in selected fields, technology transfer from related fields and human capital. Weaknesses included the lack of a flight heritage or lack of access to adequate laboratory and test infrastructure.

The publication ends with a summary covering proposals for specific actions that will contribute to further development of competencies.

Suggestions include: increasing the level of investment from the state budget, increasing the demand for satellite data in state administration, support for the entities in the field of acquiring flight heritage, investment in dedicated laboratory and test infrastructure or increase in the contribution dedicated to optional programmes in ESA.

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List of abbreviations

Abbreviation used	Meaning
ARTES	ESA programme dedicated to the commercialisation of the results of space technology research and development programmes in the field of telecommunications (Advanced Research in Telecommunication Systems)
Copernicus	European programme for the acquisition of global data regarding the state of the Earth's environment and its processing under civilian control
DLR	German Aerospace Center - Deutsches Zentrum für Luft- und Raumfahrt
EARTO	European Association of Research & Technology Organisations
EASN	European Aeronautics Science Network
ECSS	European organisation defining standards for space engineering (European Cooperation for Space Standardization)
EGNOS	European Geostationary Navigation Overlay Service
ELT	Extremely Large Telescope
EMITS	The European Space Agency's Electronic Mailing Invitation to Tender System
EO	Earth Observation
ESA	European Space Agency
ESA BIC	European Space Agency Business Incubation Centre
ESA ILO	ESO Industry Liaison Officer
ESA-STAR	ESA's System for Tendering And Registration
ESO	European Southern Observatory
ESRE	The Association of European Space Research Establishments
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites

Abbreviation used	Meaning
EUSPA	European Union Agency for the Space Programme. In the future, the GSA is to be transformed into it
EUSST	Acronym for European Union Space Surveillance and Tracking Programme
FP7	7 Framework Programme
Galileo	European satellite navigation system, jointly developed by the European Union and the European Space Agency, under civilian control
GDP	Gross Domestic Product
GNSS	Collective name for Global Navigation Satellite Systems
GOVSATCOM	European Governmental Satellite Communication Programme
GSA	European Global Navigation Satellite Systems Agency. To be transformed into EUSPA in the future
H2020	Horizon 2020
HE	Horizon Europe
IT	Information Technology
LEO	Low Earth Orbit
MEDLT	Ministry of Economic Development, Labour and Technology
MOD	Ministry of National Defence
MSE	Ministry of Science and Education
NCP	National Contact Point for Research Programmes of the European Union
NCRD	National Centre for Research and Development
NEO	Near Earth Objects
NGS	National Ground Segment
NRRP	National Recovery and Resilience Plan

Abbreviation used	Meaning
NSC	National Science Centre
NSP	National Space Programme
OECD	Organisation for Economic Co-operation and Development
PECS	Partnership on European Cooperating State
PLIIS	Polish Industry Incentive Scheme
POLSA	Polish Space Agency
PRS	Public Regulated Service of the Galileo satellite system
PSS	Polish Space Strategy
QCI	Quantum Communication Infrastructure
QKD	Quantum Key Distribution
SD	Space debris
SMES	Small and medium-sized enterprises
SRD	Strategy for Responsible Development
SRIA	Strategic Research and Innovation Agenda
SSA	Space Situational Awareness
SST	Space Surveillance and Tracking Network
SWE	Space Weather

Glossary

The term used	Meaning, interpretation
Development programme	Development programme According to the Act on the Principles of Development Policy, the document implementing the objectives of the development strategy
Downstream	Services relating to, among others, data collection, processing, storage and dissemination, as well as applications based on data derived from space-based infrastructures, such as Earth imaging, location, meteorological or telecommunications services
Geographical return	Regulated by the ESA Convention, the industrial policy of the European Space Agency is that „all Member States shall contribute in an equitable manner with reference to their financial contribution to the implementation of the European space programme and to the related development of space technologies". The return is measured by a coefficient, calculated for each country, which is the ratio between the amount of contracts actually received and the expected value (percentage of the Agency's funding multiplied by the total sum of the contracts awarded to all ESA members), taking into account the technological value of the contracts awarded
Horizon 2020	The largest research and innovation programme in the European Union. Its scope encompasses three hitherto separate programmes supporting research at EU level
Hosted payloads	Equipment dedicated and developed within the NSP carried on board satellite platforms of other countries/ international organisations/commercial operators
Institutions forming the higher education and science system	Entities listed in Article 7 of the Act of the 20th of July 2018 - Law on higher education and science (Journal of Laws of 2018, item 1668 as amended)
Mandatory programmes	ESA's programmes financed through Member States' contributions to ESA, determined in proportion to their national income
Middlestream	The ground segment, consisting of system integrators and subsystems that are independent end products of the space sector
Optional programmes	ESA's programmes financed only by participating States. They mainly cover the exploitation of space. The participation of individual countries is determined through negotiations separately for each programme

The term used	Meaning, interpretation
Polish entities	Polish entities mean any legal person established - and recognised as such - under national law which has legal personality and legal capacity
Polish Space Strategy	The strategy adopted by the Council of Ministers by the Resolution No. 6 of the 26th of January 2017(Monitor Polski of the 17th of February 2017, item no. 203), is an instrument for programming, management and coordination of state policy implemented by the Government of the Republic of Poland with regard to the space sector in cooperation with public and private entities and society
Strategy for Responsible Development (SRD)	Strategy for Responsible Development (SRD) until 2020 (with an outlook until 2030), adopted by the Council of Ministers by the Resolution No. 8 of the 14th of February 2017 (Monitor Polski of 15.03.2017, item 260)
Technology Readiness Level	Technology readiness level developed by NASA, adopted in the EU under Horizon 2020 (Commission Decision C(2014) 4995). The system for assessing the TRL level is defined by the ISO standard (ISO 16290: 2013). The TRL relating to the space sector is also used by ESA (https://artes.esa.int/sites/default/files/TRL_Handbook.pdf) and the guidelines EcSs-E-AS-11C - Adoption Notice of ISO 16290, Space systems - Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment (the 1st of October 2014)
Upstream	Space segment, consisting of manufacturers of instruments and suppliers of services necessary for the performance of physical activities in space
Volatile devices	Concept understood as devices that have been launched into space and have reached a level of technological readiness of TRL 9

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Introduction

At the current stage of development of civilisation, space has become an area that contributes significantly to technological progress. It is closely linked with the economic and social development of each country. Various organisations, associations as well as individuals, through projects undertaken for the development of space technologies or satellite techniques, participate directly or indirectly in the broadly understood development of the national space sector.

For states and organisations of all kinds, technological development of the space sector is a strategic and business resource. It enables effective functioning, existence, success and comprehensive development of society, states and organisations. It is therefore an asset to be developed and widely used. A survey of the domestic space sector conducted in 2020 by the Polish Space Agency (POLSA) together with the European Space Agency (ESA) indicates significant progress of Polish organisations in the field of development of space technologies and satellite techniques. This means that the projects undertaken not only serve and ensure the development of the organisations concerned, but also contribute to raising awareness among citizens and have an impact on increasing the broadly understood security of our country.

The Polish space sector currently consists of several dozen very active organisations - small and medium enterprises (SMEs), several branches of key European space companies and large companies operating in the ICT and aerospace sectors, as well as research and development institutions and universities. Additionally, an important segment of organisations operating in the Polish space sector are entities of the public administration, which can create demand for solutions resulting from the development of space technologies or satellite techniques, e.g. for satellite data, which among other things, serve as means of improving the efficiency of work and operations in public administration. Among the organisations comprising the public administration there are also institutions responsible for shaping the national space policy. Here, the leading role is played by the Ministry

of Economic Development, Labour and Technology (MEDLT) together with POLSA, which plays the role of an executive agency of the above mentioned Ministry. Additionally, a representative of the Ministry of Labour and Technology Development acts as the head of the Polish delegation to the ESA, coordinating, among others, the activities of delegates (representatives of key government departments) in individual programme groups.

This study is based on multiple sources, including reports and surveys from international organisations, i.e. the ESA, the European Union (EU), and national organisations, i.e. the National Centre for Research and Development (NCRD) and the National Science Centre (NCN). An added value is the information provided by representatives of the Polish space sector (scientific and research units, industry) during visits of employees of the Department of Strategy and International Cooperation (DSWM) of POLSA to the above-mentioned organisations. Additionally, this study is a continuation of activities undertaken by POLSA in 2016 and 2017. Since then, a number of important events have taken place, which have significantly contributed to changes in the Polish space sector. These include:

- Adoption, by the Resolution of the Council of Ministers of the 26th of January 2017 (Monitor Polski of the 17th of February 2017, item 203), of the Polish Space Strategy, which defines the objectives and areas of intervention until 2030, together with the commencement of the development of the National Space Programme (NSP - National Space Programme);
- Polish Industry Support Programme (PLIIS) dedicated to building the capacity of the young Polish space industry sector, which was completed in 2019. Since then, Polish entities that want to participate in the execution of contracts for the ESA have to compete with international organisations operating on the European market;
- ESA's Ministerial Council, held in November 2019, which shapes the actions taken for the benefit of the European space industry for the next years.

In view of the above and POLSA's statutory (Journal of Laws of 2019, item 1793) as well as regulatory tasks, the need arises to repeat the survey of the Polish space sector, supplemented with up-to-date and comprehensive information. Such needs are addressed in this study, in which the discussed research results aim at enriching the knowledge on the current state, trends and technologies in the national and international context. Additionally, the study includes a list of the most promising technological areas of the Polish space sector.

Due to the limitations of POLSA's and ESA's arrangements, the survey was conducted among those entities of the Polish space sector, which responded to the Polish Space Sector Evaluation 2020 survey and passed the verification process (interesting/prospective) conducted by the DSWM POLSA and ESA representatives. However, the data obtained from the surveys and directly from Polish organisations may be subject to some error due to the fact that some organisations completed the questionnaires in a general manner, hence the aggregate data obtained by POLSA may be incomplete. As a result of the verification of the questionnaires, representatives of POLSA and ESA selected 22 entities from all over the country, of which 20 were willing to participate in an in-depth survey. Additionally, due to the involvement of ESA representatives in the project, e.g. through their participation in visits to representatives of the Polish space sector and the provision of internal information, a significant part of this study is devoted to the area related to ESA activities.

1. General description of the Polish space sector

Space is one of the most demanding operating environments. Equipment launched into space must undergo detailed and multi-stage verification to ensure its reliability, availability and full operability under demanding space conditions (cosmic radiation, magnetic forces and low gravity). Due to the different areas of operation, the sector can be divided into three categories: upstream, middlestream and downstream.

Upstream is otherwise known as the space segment, consisting of manufacturers of instruments, equipment as well as providers of services necessary to carry out physical activities in space. Middlestream, on the other hand, refers to the ground segment, which includes system integrators and subsystems that are stand-alone end products of the space sector. The last category, downstream, includes services relating to, among others, data collection, processing, storage and sharing, as well as applications based on data acquired from space-based infrastructure, such as Earth imaging, location-based, meteorological or telecommunications services. It should be emphasised that since the very beginning of the involvement of Polish entities in this sector, and in particular since Poland's accession to the European Space Agency (November 2012), Polish entities have been conducting research and development, production and service activities in all of the above-mentioned categories.

Due to the international context of activities in this sector, Polish entities develop their technologies for the needs of the space sector according to the so-called Technology Readiness Levels (TRL). A simplified diagram of the technology levels used by national entities is presented below:

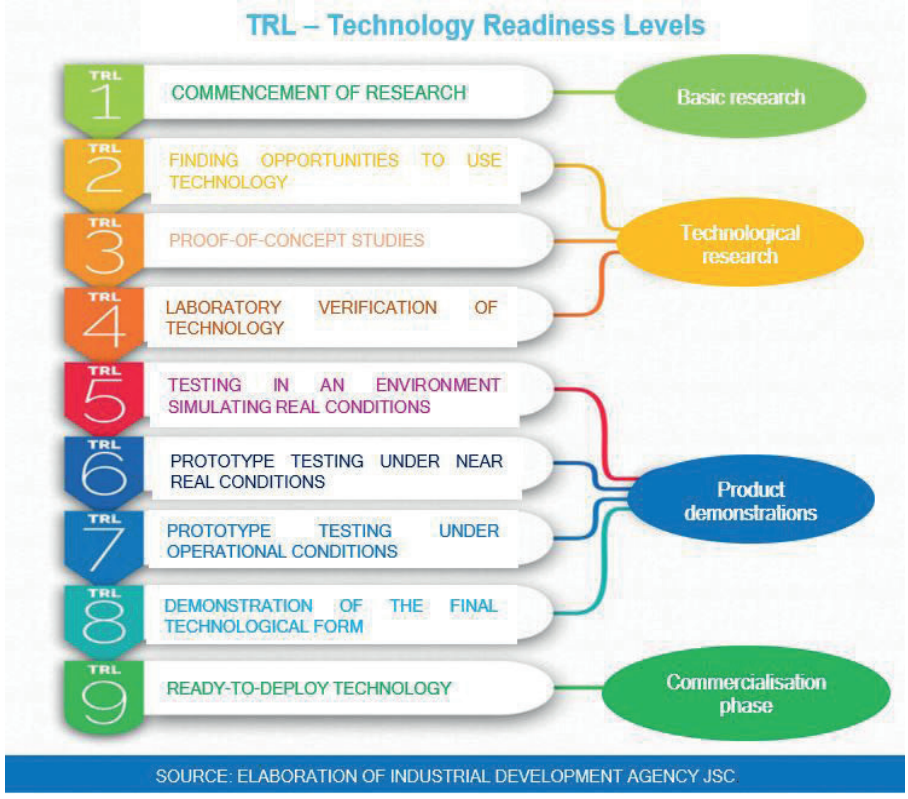

Figure 1 Simplified technology breakdown diagram
Source: ARP S.A.

Since the very beginning (i.e. since 2008 - the beginning of the implementation of the PECS pre-accession programme) of the cooperation with the most important client and partner, i.e. ESA, Polish entities have been following the most important documents and guidelines of this agency or organisations closely cooperating with it, including:

- The ESA Technology Tree (ESA Technology Tree, Version 4.0, 2020 reference: STM-277 3rd ed.), which divides space technologies into 26 domains and over 100 sub-domains;
- Product Tree (ESA Generic Product Tree, 2011, reference: TEC-TP/0045), which contains the product classification of the finished

devices, including: components, subsystems as well as systems;
- European unified standards related to R&D activities and manufacturing for the space sector, developed by the European Cooperation for Space Standardisation, ECSS (more information: www.ecss.nl.).

The size of the Polish space sector can be estimated on the basis of entities registered on the ESA's System for Tendering And Registration portal. In August 2020, there were 331 entities from Poland. The sector's entity structure is dominated by enterprises from the SME sector. Research and development entities also constitute a significant group.

The Polish space sector is clearly differentiated between the scientific and the industrial part. Polish institutions forming the system of higher education and science (several dozen centres in total) have many years of experience in space activities and significant achievements in this area, especially in the construction of research instruments for scientific and educational missions and elements for satellites, as well as in processing data obtained from space. The scientific sector maintains active international cooperation with leading centres in Europe and worldwide. Particularly noteworthy are the achievements and accomplishments of the Space Research Centre of the Polish Academy of Sciences, which for over 40 years has been performing space activities, both in the field of scientific research and technology development, while also participating in many important ESA missions.

The industrial part of the Polish space sector looks different. It is a young sector, dominated by small and medium-sized enterprises. The areas of specialisation in which Polish entities develop include space and ground software, precision mechanics, robotic solutions, optics, optoelectronics, avionics, orbit orientation and correction systems, power systems, structures, material technologies and composites as well as propellant technologies. Great potential also exists in space observation systems, both optical and radar. Moreover, Polish companies offer a large number of services based on the use

of satellite techniques. In the last few years, many innovative applications have been developed in the area of satellite imaging, satellite navigation and satellite communications.

Due to easy, unlimited and in many cases free of charge access to European satellite resources and data from flagship programmes of the European Union, such as Copernicus, Galileo and GovSatCom, the market of applications based on satellite imaging, navigation and communication is currently developing very dynamically in Poland. This is also due to very high demand of end users for products that can be used in many areas of economic and social life, including all types of transport, spatial management, environmental monitoring and management, energy, agriculture, fisheries, insurance and banking, defence, security and crisis management. It is worth noting that there is a gradual increase in awareness of the importance of such data and the benefits of its use by public administrations at various levels. This is because the administration is more and more often reaching for applicationsand services using satellite imagery. A very wide range of potential applications of satellite data is shown in the diagram below:

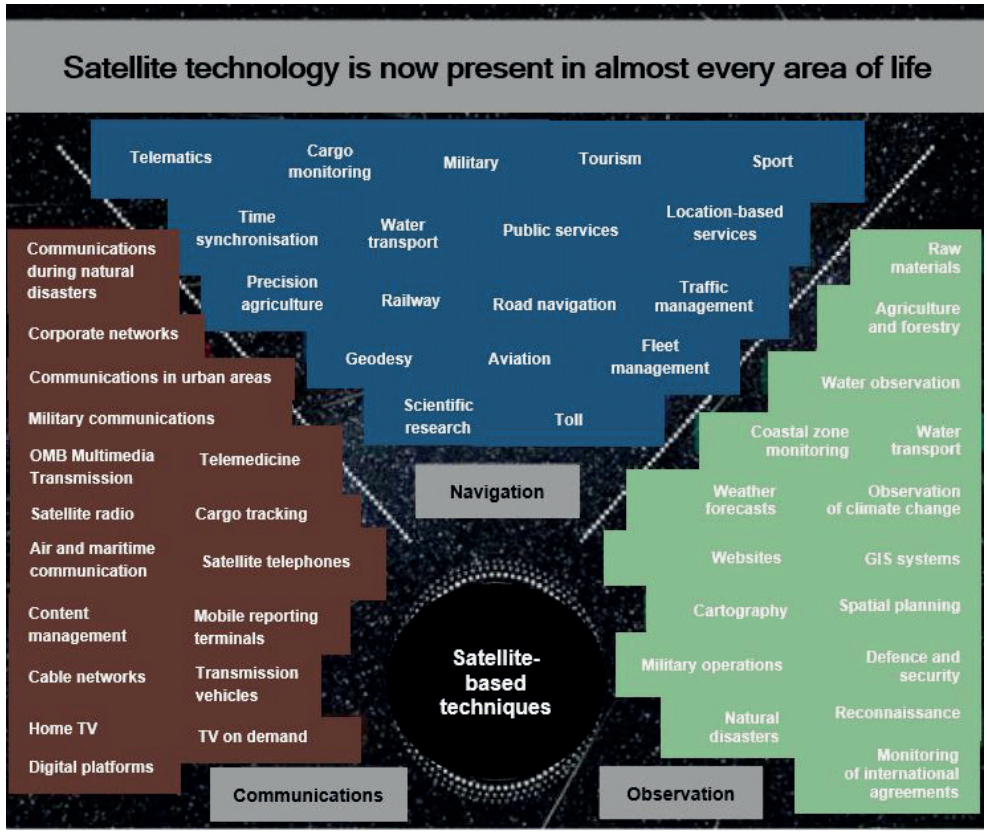

Figure 2 Diagram of the potential application of satellite data
Source: Ministry of Development, Labour and Technology; supporting materials for the Polish Space Strategy

In the space sector, the following 4 levels of development (Tiers) of companies can be distinguished:

- Tier I - mission integrators (the so-called Large System Integrators - LSI, 3 leading European companies: Airbus D&S, Thales Alenia Space and OHB);
- Tier II - systems integrators;
- Tier III - subsystems integrators;
- Tier IV - suppliers of technology and components (current Polish level).

Despite the fact that most Polish entities are component suppliers, there is a growing trend of increasing technological competence and ability to manage larger projects by Polish entities, as well as an increase in their turnover. In this way, there are already companies and scientific and research institutes in our country which play the role of integrators of subsystems or even entire systems.

The involvement of Polish entities in activities of this sector may be assigned to several areas, such as Earth observation, satellite communications, navigation, space security, science, launch systems as well as orbital and planetary exploration. Based on the current involvement of national entities in national and international programmes (within ESA, EU, EUSPA or EUMETSAT), the most important activities in Poland include: Earth observation, space safety and satellite communications.

Polish entities are very active in acquiring and implementing projects in the field of Earth observation, in particular in the field of methods of data processing as well as analysis and building applications for data use by interested entities both on a global, regional and local level. The activity of Polish entities in the field of space security focuses on protecting the infrastructure and people on Earth from the effects of these threats, as well as tracking and monitoring possible dangers and threats (both natural and artificial) connected with the space environment. The activity of national entities in the field of satellite communications is in line with both the flagship space programme of the European Union, i.e. GOVSATCOM, as well as missions and programmes of ESA, especially from the group of programmes dedicated to satellite communications - and ARTES applications.

2. Detailed description of the Polish space sector

a. Size of the Polish space sector

Definition of the Polish space sector

Following the Organisation for Economic Co-operation and Development (OECD), the Polish space sector can be considered as „all entities involved in the systematic application of engineering and scientific fields for the purpose of the exploration and use of outer space"[1].

The size of the Polish space sector can be estimated based on entities registered on the European Space Agency's portal for registration and tendering - STAR (ESA's System for Tendering And Registration). In August 2020, there were 331 entities from Poland, which is less than in 2019 (over 420 entities). This decrease can be explained by ESA's verification of entities and the deletion from the system of those that ceased to cooperate with ESA or ceased to exist.

As calculated, 79% of the entities registered in ESA - STAR were enterprises (of which 40% had the status of small and medium enterprises). The data shows that 156 enterprises participated in ESA contracts (as main contractors or subcontractors) between 2015 and the first quarter of 2020.

[1] *Report of the Polish Space Agency „Polish space sector. Entity structure - development opportunities - raising funds", edited by dr Marta E. Wachowicz, Warsaw, 2017, p. 20. Accessed: https://polsa.gov.pl/images/docs/Polski_Sektor_Kosmiczny_Struktura_podmiotowa_Mozliwosci_ development_pozyskiwanie_srodkow.pdf.*

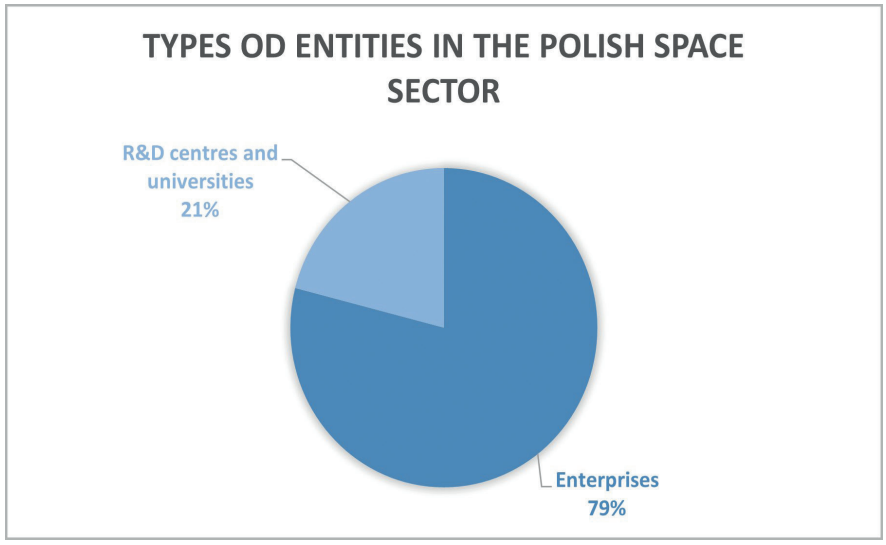

Figure 3 Types of entities of the Polish space sector - by ESA EMITS registration (August 2020)

The data presented in this report comes from the Polish Space Sector Evaluation 2020 survey prepared by ESA and POLSA. It was sent between March and June 2020 to 99 entities of the Polish space sector. Responses were received from 50 of them, i.e. 42 companies and 8 research and development units. It can be debated whether 50 entities constitute a representative group and whether conclusions should be drawn on this basis for the entire sector, but this is the only reliable data currently available to POLSA. The data illustrate the state at the end of 2019. On its basis, it can be concluded that:

- 60% (30 entities) had SME status; 40% (20 entities) had large company status;
- Almost 3/4 of the entities (74% or 37 entities) were established in 2001 or later;
- These entities employed a total of around 11,600 people in 2019.

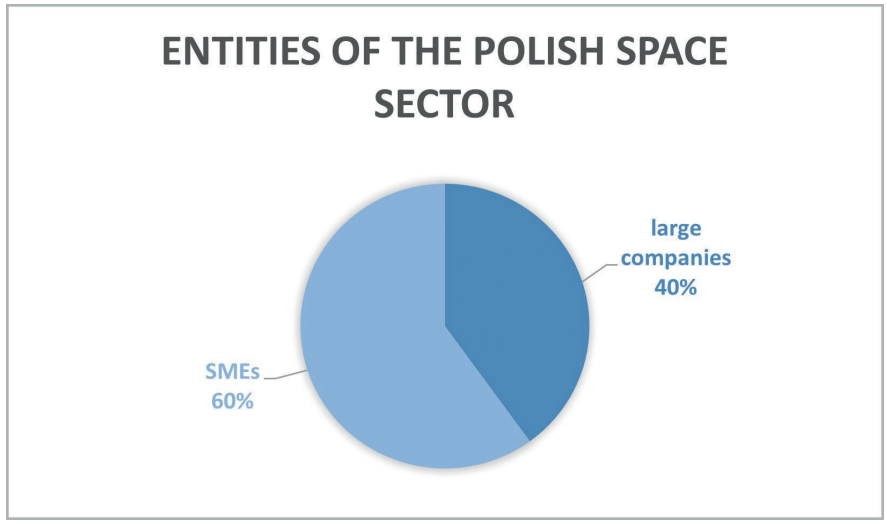

Figure 4 Types of Polish space sector entities participating in the POLSA/ESA survey

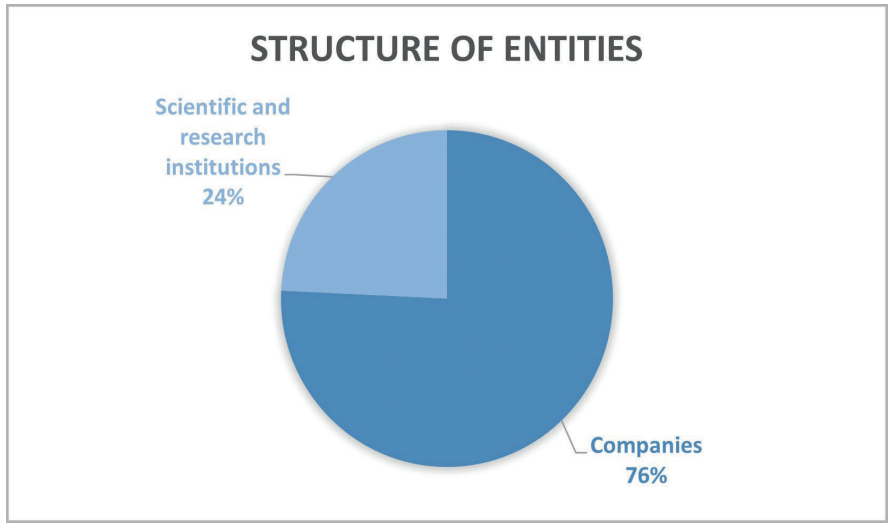

Figure 5 Structure of the Polish space sector entities participating in the POLSA/ ESA survey

b. Participation in national projects

Projects related to the development of space technologies and satellite techniques funded by national public sector institutions come primarily from various horizontal support programmes offered by the National Centre for Research and Development (NCRD) and the National Science Centre (NSC).

The National Centre for Research and Development has been financing research and development works in many innovative fields and industries, including the aerospace sector. It should be emphasised that National Centre for Research and Development has many different programmes, which are also available to companies and research units developing space technologies or satellite techniques. One of them is the fast track named „Space Technologies". Compared to other programmes, the National Centre for Research and Development has the advantage that the programme finances projects at a high level of technological readiness, which are intended for commercialisation, i.e. the ready products and services which may find their market application are to be the results of the projects under the aforementioned programme.

In recent years, a significant amount of budgetary funds has been allocated by National Centre for Research and Development under the Centre's fast track programme called „Space Technologies". The programme is financed from structural funds and partially from the state budget. The last competition for co-financing of industrial research and development works financed by the Intelligent Development Operational Programme, in the competition 5/1.1.1/2019 - „Fast Track - Space Technologies", was announced by the National Centre for Research and Development in 2019. Its aim was to enable Polish entities to raise the level of technological readiness of their developed solutions to at least TRL 7 in order to increase their attractiveness according to the requirements of, among others, ESA and large space systems integrators.

The competition was concluded in February 2020. It received 33 applications. NCRD has finally selected 15 projects for co-financing for the total amount of PLN 143.8 million. In the group of initiatives positively evaluated and qualified for financing, 7 were submitted by enterprises and centres located in the Mazowieckie Voivodeship, and another 8 in other regions of Poland. The amount of 70.2 million PLN was allocated for projects implemented by entities from the Mazowieckie Voivodeship. Whereas, the co-financing for the remaining beneficiaries amounted to 73.6 million PLN. The individual grant amounts ranged from 1.5 million PLN to over 33 million PLN.

The thematic scope of the projects includes such areas of activity as satellite earth observation, satellite data processing, chemical and electrical propulsion technologies, microwave communication technologies and components, small satellite systems and subsystems, mechanical systems, satellite infrastructure testing and launching systems.

From the information received during the survey from some of the Polish entities whose projects were qualified for implementation under the „Fast Track - Space Technologies" competition, it appears that ultimately some projects were not launched by the beneficiaries.

Surveys and visits to selected entities of the Polish space sector have shown that the following projects are currently being implemented with NCRD funds under the fast track:

Name of the project	Contractor	Result/product at the end of the project Final TRL	Final TRL
„A smart on-board computer for nano- and microsatellites with improved reliability and increased computing power, allowing self-diagnosis of the satellite in orbit using machine learning algorithms for anomaly detection in telemetry data"	KP Labs Sp. z o.o.	The on-board computer, named Antilope, will be the most important element of the satellite, responsible for its control and performing the most important tasks, such as communication with the ground station, collecting information on the status of the satellite's subsystems and operating both the classical FDIR mechanism (Fault Detection, Isolation and Recovery) and the FDIR intelligent system based on artificial neural networks analysing telemetric data in search of point, context and collective anomalies. Moreover, it is planned to use the computer during the future Warsaw University of Technology PW Sat-3 mission.	TRL 9
„ASTRO-MODULES - set of function blocks for small and medium satellites"	Astronika Sp. z o.o.	Development of three satellite subsystems for satellite systems with a mass of 50-500 kg and dimensions 6Ux6Ux6U, including solar panel opening and separation subsystems.	TRL 8
„Development of an ultra-lightweight 100 kN rocket motor assembly support structure for space applications"	CIM-mes Projekt Sp. z o.o.	The development of a 50 kg optical Earth observation satellite with dimensions of 40x40x50 cm and a resolution of less than 2 m. Refinement of a number of subsystems for the microsatellite to flight level is another result.	TRL 9

Name of the project	Contractor	Result/product at the end of the project Final TRL	Final TRL
„EagleEye microsatellite system”	Creotech Instruments SA	The development of a 50 kg optical Earth observation satellite with dimensions of 40x40x50 cm and a resolution of less than 2 m. Refinement of a number of subsystems for the microsatellite to flight level is another result.	TRL 9
„System to support response to sudden natural events by generating geo-information extracted from automatic analysis of optical and radar satellite products”	Eversis Sp. z o.o.	A working prototype of the system implementing a minimum of two full cycle scenarios for processing and making results available to end-users. Results of verification of accuracy and efficiency of processing chains on real data	TRL 8
„Development and field testing of an in-orbit control and attitude control module for micro observation satellites”	Iceye Polska Sp. z o.o.	Design, construction and testing of a satellite control and orientation determination module for observation microsatellites. It will offer triaxial estimation and triaxial orientation control of the satellite	TRL 9
„Temperature memory coatings for space technology research and development”	Łukasiewicz Research Network - Institute of Aviation	Development of temperature-memory coating technologies that enable measurements in places difficult to access with the use of the standard measurement techniques, in the presence of reactive flow and strong radiative heat exchange	TRL 7
„Pulsed plasma propulsion for nano- and microsatellites”	Institute of Plasma Physics and Laser Micro--Fusion and Progresja Space Sp. z o.o.	Development of a plasma propulsion system for nano- and microsatellites, using as fuel a warm fluorine polymer with very low saturated vapour pressure	TRL 7
„GNSS receiver hardware and software front-end to make the navigation system immune to attacks by jamming signals”	Rectangle Sp. z o.o	Developed and ready section of the new generation GNSS receiver responsible for optimisation of radio signal reception, significant improvement in the protection of the receiver against interference and radio attacks, as well as improvement in receiver performance. Obtaining the above-mentioned functional advantages will be possible thanks to the development of an innovative hardware and software structure of a three-band multi-constellation radio front-end equipped with software for detection and elimination of a number of unwanted radio interferences.	TRL 7

Name of the project	Contractor	Result/product at the end of the project Final TRL	Final TRL
„Preparation and implementation of innovative software for efficient, accurate astrometry and photometry of point and streak sources for astronomical CCD and CMOS cameras”	Sybilla Technologies Sp. z o.o.	Development of fully functional, innovative software, together with a pilot infrastructure, for the acquisition, processing, storage and presentation of large volumes of optical space observations	TRL 8
„Development of a revolutionary Earth imaging service using the REC satellite constellation”	Sat Revolution S.A.	The aim of the project is to develop, build and test in orbit an innovative nanosatellite platform that will allow for the conduct of experiments, research and commercial and scientific tests during a single satellite mission. This will reduce the costs of such missions by spreading the fixed costs, i.e. platform, launch, permits, etc., among all the institutions participating in a given mission	TRL 9
„Development of an automated system based on a set of hybrid algorithms of artificial intelligence and satellite imaging for mapping and monitoring the state of the infrastructural network of technical land development”	SPOTTIT Sp. z o.o.	This is a 26-month project that started on the 15th of June 2020. While the project is still at an early stage, the team is already able to provide a range of manual mapping and monitoring of power, gas and water networks derived from analysis of satellite images. The team will continue to develop selected research areas to provide additional analysis, fully automate workflows and improve algorithm accuracy	TRL 6
„Improving the technological readiness of S- and X-band communication system products/components”	WiRan Sp. z o.o.	Development of a set of four significantly improved volatile component products for use in micro and nanosatellites: • a duplexer for Sband, • a duplexer for X band, • antennas for S band, • antennas for X band. They will constitute a critical part of the satellite's radio communication path. The set of the above-mentioned components will constitute the first complete set of satellite communications in S band and X band manufactured in Poland, to be installed on nano- and microsatellites	TRL 9

Name of the project	Contractor	Result/product at the end of the project Final TRL	Final TRL
„Development of a three-stage suborbital launch rocket system for payloads”	Wojskowe Zakłady Lotnicze Nr1 S.A. (leader) in a consortium with scientific and industrial entities: Military Institute of Armament Technology and Special Production Plant „Gamrat” Sp. z o.o.	The aim of the project is to develop and manufacture a three-stage recoverable suborbital rocket and perform a demonstration flight above the Karman line (at least 100 km altitude) with a load of up to 40 kg. The possibility of offering a commercial suborbital flight service for entities wishing to conduct research in the fields of biology, chemistry, physics, and materials research in microgravity conditions will be a measurable result.	Suborbital rocket - at least TRL level 8. Other individual subsystems, including engines: TRL 9

(*) As of 31.12.2020, the project has not yet started, because the entity has not yet received confirmation from the final customer/recipient of its interest in the project results.

Table 1 Projects implemented with NCRD funds as part of fast track

Apart from the aforementioned programme, NCRD has a number of different programmes which are also available to companies and scientific and research entities developing space technologies or satellite techniques. These include strategic programmes (Gospostrateg, Technostrateg, Infostrateg), tools aimed at international cooperation and joint projects with other countries (EUREKA, ERANET, Bonus, Eurostar), programmes financed from structural funds (OP Intelligent Economy, OP Innovative Development), Applied Research Programme, support instruments aimed at commercialisation of R&D activities (SPIN-TECH, INNOTECH). In the last five years, more than 40 projects have been financed with the above instruments. They were used by companies as well as universities and scientific and research institutes. They concern both space exploration and exploitation, as well as the use of satellite data and its processing and the creation of applications for end users in many ground application areas, such as transport and telecommunications, environmental protection, health care and agriculture.

A detailed list of projects from other NCRD programmes is attached as Annex No. 1 to this study.

The National Science Centre has funded over 300 research projects in the last five years (2015-2020). Their value is over PLN 212 million. They mainly concerned basic sciences (physics, astrophysics, mathematics), life and earth sciences, astronomy, process and production engineering, astronomy and space research, systems engineering and telecommunications, computer science and information technologies, quantum optics and quantum information, theory of relativity and gravitation, gas and plasma physics, electricity and magnetism, nuclear and atomic physics, materials and materials research (including metals, polymers, composites). They were mainly carried out by universities, mainly of a technical profile, as well as research and development institutes, such as the Space Research Centre of the Polish Academy of Sciences (CBK PAN), the Nicolaus Copernicus Astronomical Centre (CAMK), the Institute of Geodesy and Cartography (IGiK), as well as institutes belonging to the Łukasiewicz Research Network (the Institute of Aviation, the Industrial Institute of Automation and Measurements - PIAP, the Institute of Electronic Materials Technology - ITME). The projects mostly concerned theoretical and laboratory research at the lowest level of technological readiness, i.e. at the initial stage of work, such as observation and description of the basic principles of a given phenomenon, scientific research on the basic properties of a technology, definition of a technology concept or its future applications (even though no evidence or detailed analysis confirming the assumptions made exists yet). Other projects, on the other hand, consisted of analytical and experimental confirmation of critical functions or technology concepts or selected technology components.

c. Participation in international projects

ESA

In 1994, Poland signed an agreement with the ESA on cooperation in the field of peaceful use of space, which was later extended in 2002. Based on this agreement, Polish entities could participate in ESA's scientific programmes, which resulted in the presence of Polish equipment on most of the Agency's flagship research missions - Cassini-Huygens, Integral, Mars Express, Rosetta, Venus Express or Herschel. Currently Poland is also designing and building subsystems for ESA missions: Juice, Athena and Ariel. At the same time the first Polish private companies offering services based on satellite techniques started to emerge. The beginning of the 21st century brought intensification of cooperation with ESA. In 2007, the Agreement on a European Cooperating State (PECS) was signed. Thanks to the creation of this mechanism, 52 projects were financed for a total amount of €12 million, implemented in cooperation with ESA by Polish companies, research institutions and universities.

Poland became the 20th member of the ESA on the 31st of July 2012. After a transition period of seven years, in 2020 our country entered a new stage of membership in this organisation without preferential conditions for Polish entities.

In 2019, a support programme dedicated to Polish entities - the Polish Industry Incentive Scheme (PLIIS) 2012-2019 - came to an end. For the duration of the programme, 45% of the Polish mandatory contribution to ESA was allocated to PLIIS. It was aimed at adapting Polish industry, operators, the scientific community and other entities operating in Poland to the requirements of the European Space Agency. The total amount of PLIIS for the Polish space sector was €65 million (seven-year perspective).

The ESA has two types of programmes: mandatory programmes, in which all Member States are obliged to participate and contributions are calculated on the basis of GDP, and optional programmes, which are financed by the participating countries in amounts declared during ESA's periodic Ministerial Councils.

At the ESA Ministerial Council in 2016, the Polish contribution to optional programmes amounted to €45 million for the period 2016-2019[2].
On the 27-28th of November 2019, the ESA Space19+ Ministerial

[2] *ESA/C(2016)100, rev.6 Paris, the 12th of December 2016.*

Council took place in Seville, where the ministers of Member States responsible for space policy decided which space programmes implemented by the European Space Agency will be financially supported in the next years. The Polish delegation declared a financial contribution to individual optional programmes for 2020-2022 in the following amounts:

- Space Safety Programme - S2P (€ 9.9 million);
- Earth Observation – EO (8,5 mln euro)
- Programme of Advanced Research in Telecommunications Systems – ARTES 4.0 (7,3 mln euro)
- European Exploration Envelope Programme, Period 2 – E3P-2 (6 mln euro)
- PRODEX (4 mln euro)
- General Support Technology Programme – GSTP (3 mln euro)
- NAVISP Phase 2 (0,3 mln euro)

The total declared allocation for optional programmes amounted to €39[3] million.

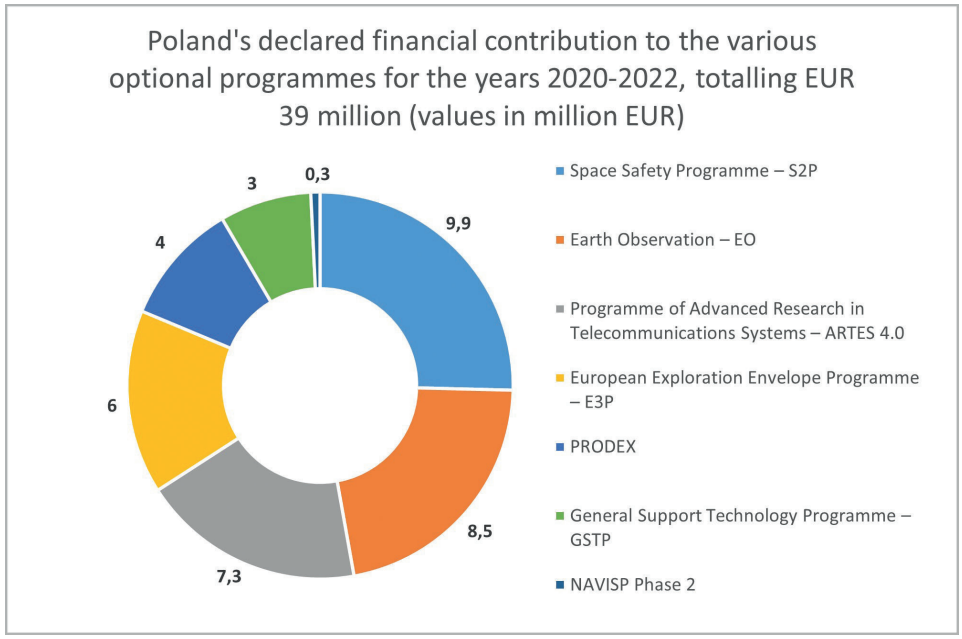

Figure 6 Poland's declared financial contribution to individual ESA optional programmes for 2020-2022, in total EUR 39 million
Source: own study

[3] *ESA/C-M(2019)100, rev.6 Paris, the 2nd of December 2019.*

A detailed breakdown of funds for the specific elements of the programmes is shown in the table below:

Programme	Element	Duration of the programme	Amount (in EUR million)
Future Earth Observation Programme	Future EO Segment 1	2020-2022	4,7
Copernicus Segment 4		2020-2028	3,8
ARTES 4.0	Future Preparation	2020-2023	0,3
ARTES 4.0	Core Competitiveness	2020-2023	1,0
ARTES 4.0	Optical Communication – ScyLight	2020-2025	3,0
ARTES 4.0	Business Applications Space Solutions		2,0
ARTES 4.0	Space Systems for Safety and Security	2020-2025	1,0
Navigation Innovation and Support Programme Phase 2	Element 2 „Competitiveness”	2020-2022	0,3
Space Safety Programme	Core Activities	2020-2022	4,0
Space Safety Programme	Cornerstone Mission 3 ADRIOS	2020-2022	5,9
Space Exploration	European Exploration Envelope Programme 2nd period	2020-2022	1,5
Space Exploration	ExPeRT	2020-2022	2,3
Space Exploration	Lunar Robotic Exploration	2020-2022	1,0
Space Exploration	Mars Robotic Exploration	2020-2022	1,2
General Support Technology Programme	Element 1 „Develop”	2020-2022	1,5
General Support Technology Programme	Element 2 „Make”	2020-2022	1,5
PRODEX			4,0

Table 2 Allocation of funds to specific programme elements

For 2020, Poland's contribution to ESA is as follows:

- Mandatory programmes: €24 million;
- Optional programmes: €14 million.

As of August 2020, 331 entities were registered on the ESA - STAR portal. Of these, 79% are industrial entities, among which 40% are SMEs. In turn, 156 of them managed to win contracts between 2015 and the first quarter of 2020.

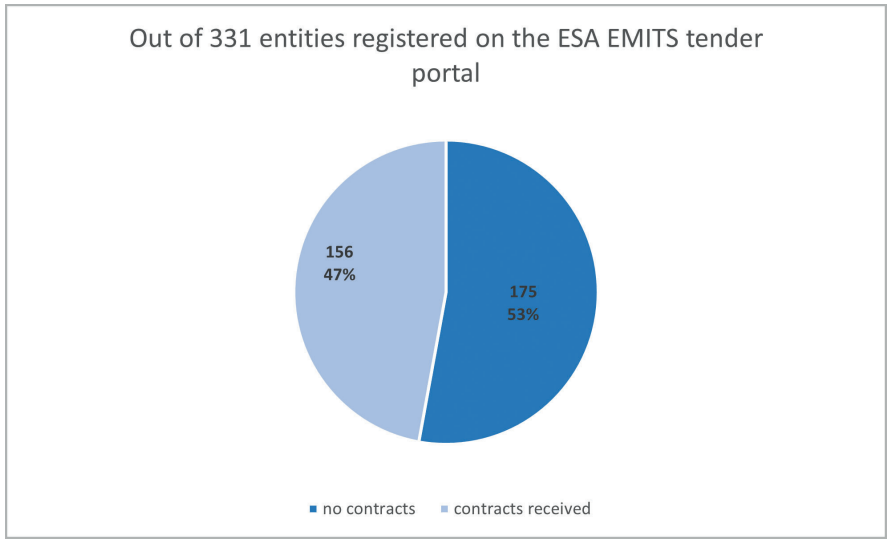

Figure 7 Breakdown of entities that were awarded ESA contracts among the 331 entities registered on the ESA procurement portal
Source: own study based on European Space Agency report „Analysis of Industrial participation of Polish industry to ESA Programmes 2015-1Q2020"

Polish activities on the ESA forum are handled by the Polish delegation to the European Space Agency. The delegation participates in specialised panels dealing with specific issues or programmes. Within ESA, in addition to the Head of Delegation, the Council, the Council Working Group and the Finance Committee, in which representatives of the Ministry responsible for economy participate, Polish delegates take part in the following bodies:

- Industrial Policy Committee (IPC);
- IPC-THAG;
- International Relations Committee (IRC);

- Security Committee (SEC);
- InfoSec Panel;
- Science Programme Committee (SPC);
- Joint Board on Communication Satellite Programme (JCB);
- Launchers Programme Board (PB-LAU);
- Programme Board for Earth Observation (PB-EO);
- PB-EO / DOSTAG;
- Programme Board for Human Spaceflight, Microgravity and Exploration (PB-HME);
- HME-EUB;
- Programme Board on Satellite Navigation (PB-NAV);
- Programme Board on Space Situational Awareness (PB-SSA).

The Polish delegation to ESA includes representatives of the Polish Space Agency, the Ministry of Economy, the Ministry of Science, the Ministry of National Defence, the Ministry of Interior and Public Administration, the Ministry of Foreign Affairs, the Ministry of Digitalisation, the Ministry of Infrastructure and the Nicolaus Copernicus Astronomical Centre.

ESA's programmes

The following section will present data related to all ESA's programmes, both optional and mandatory. The next subsection will discuss in detail the Polish Industry Incentive Scheme (PLIIS), a support programme in 2012-2019 for Polish entities. For the duration of the PLIIS programme, Poland has allocated almost half of the mandatory contribution. It was designed to adapt Polish industry, operators, the scientific community and other entities operating in Poland to the requirements of the ESA[4].

The distribution of ESA funds for Polish entities is presented below, broken down into individual ESA thematic areas in the period between 2015 and the first quarter of 2020 (amounts in million €):

[4] The information in this subsection is based on surveys from entities and the ESA report „Analysis of Industrial participation of Polish industry to ESA Programmes 2015-1Q2020".

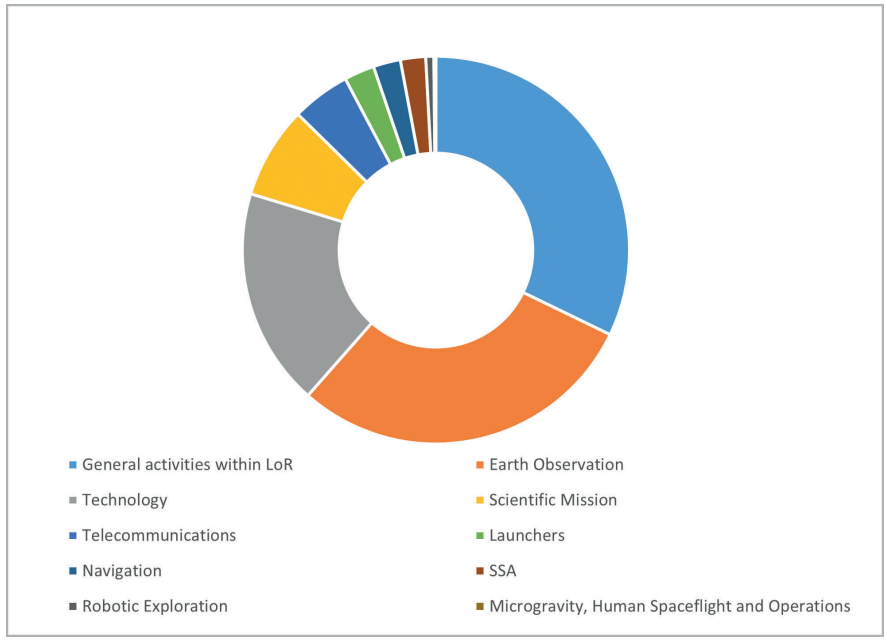

Figure 8 Amounts of ESA funds for Polish entities divided by individual ESA thematic areas (period 2015-Q1 2020, amounts in EUR million)
Source: own study based on European Space Agency report „Analysis of Industrial participation of Polish industry to ESA Programmes 2015-1Q2020"

The graph above shows that most of the funds in Poland were consumed in programmes such as general activities, for which a letter of recommendation from the Polish delegation to ESA or a task force is required (in the case of PLIIS). The second place is occupied by the area related to Earth observation. It is worth noting that these two areas account for 61 percent of the total. Next, with a fairly high score, is the area related to the development of generic technologies, accounting for 18 percent.

The chart below shows the amount of funding for Polish entities in each of the main ESA programmes or missions (between 2015 and the first quarter of 2020, amounts in million €):

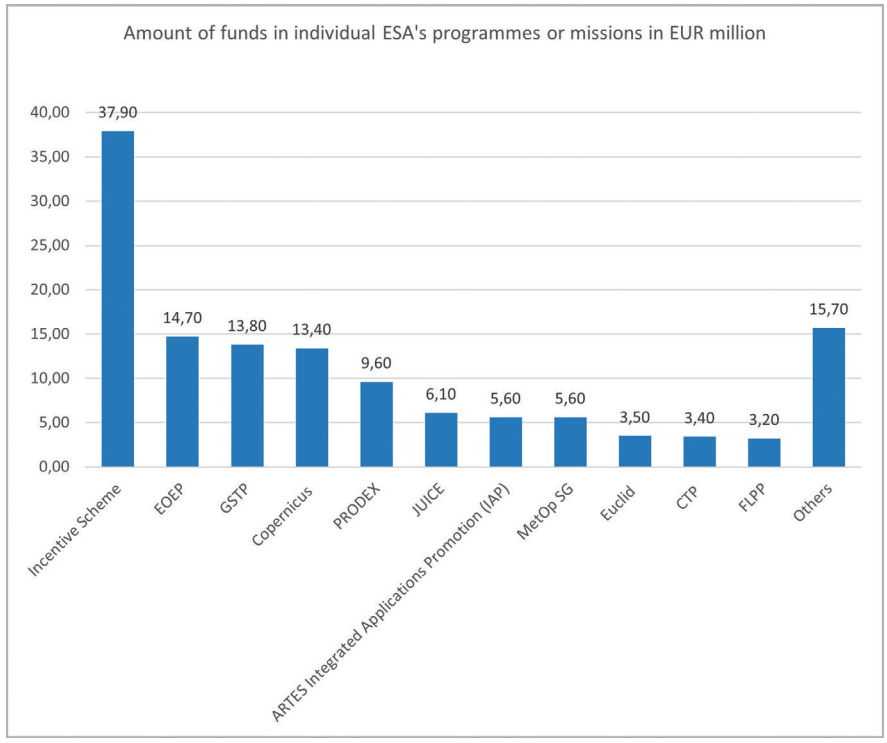

Figure 9 Distribution of funds to Polish entities in ESA main programmes and missions
Source: own study based on surveys from Polish entities and European Space Agency report „Analysis of Industrial participation of Polish industry to ESA Programmes 2015- 1Q2020"

As can be seen from the chart above, the most funds for Polish entities were allocated from the PLIIS programme dedicated to Polish entities. The next three places are taken by the following programmes: Earth Observation Envelope Programme, General Support Technology Programme and Copernicus. These four programmes together account for about 60% of the total funds for Polish entities. Based on the data presented, it can be concluded that activities and projects related to Earth observation and development of general technologies are very popular among Polish entities.

In addition, the chart below shows the distribution of funds to Polish entities divided by ESA programme type (between 2015 and the first quarter of 2020, amounts in million €):

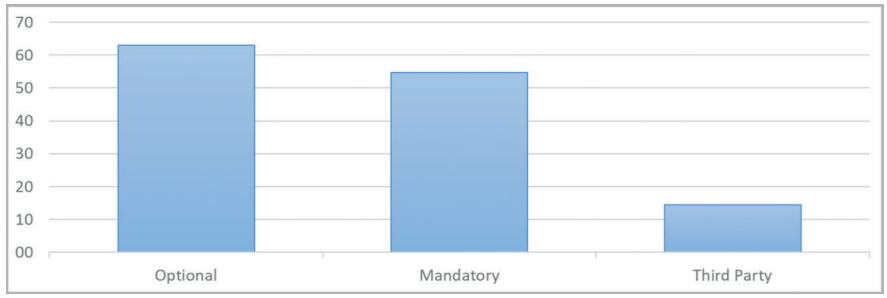

Figure 10 Distribution of funds to Polish entities divided by ESA programme type (EUR million)
Source: European Space Agency report „Analysis of Industrial participation of Polish industry to ESA Programmes 2015-1Q2020"

It is worth noting that more funds were allocated from ESA optional programmes. The high ratio in mandatory programmes is also due to the dedicated PLIIS programme.

The chart below shows the distribution of funds in ESA science programmes by individual missions in € million. The largest share of Polish entities in terms of amounts is in the JUICE scientific mission.

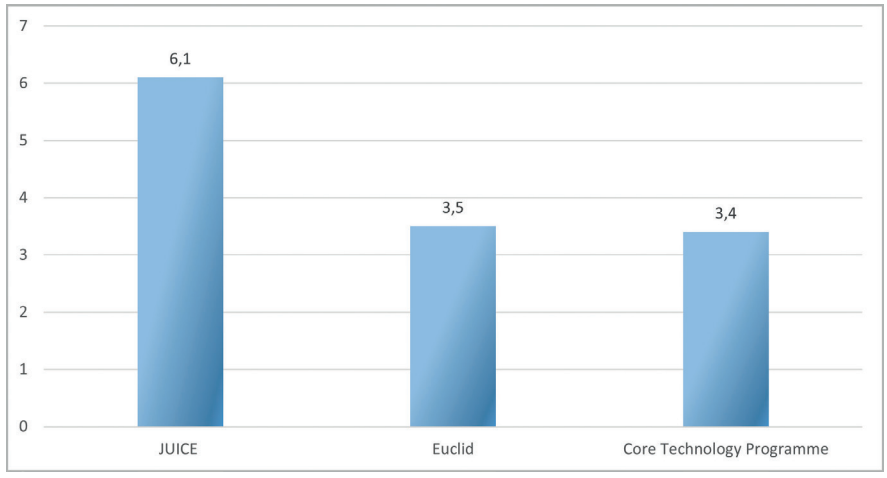

Figure 11 Distribution of funds to Polish entities divided by missions in the Science programme
Source: own study based on surveys from Polish entities and European Space Agency report „Analysis of Industrial participation of Polish industry to ESA Programmes 2015- 1Q2020"

The chart below shows the quarterly distribution of funds in million € for Polish entities in ESA's programmes/missions (between 2015 and the first quarter of 2020):

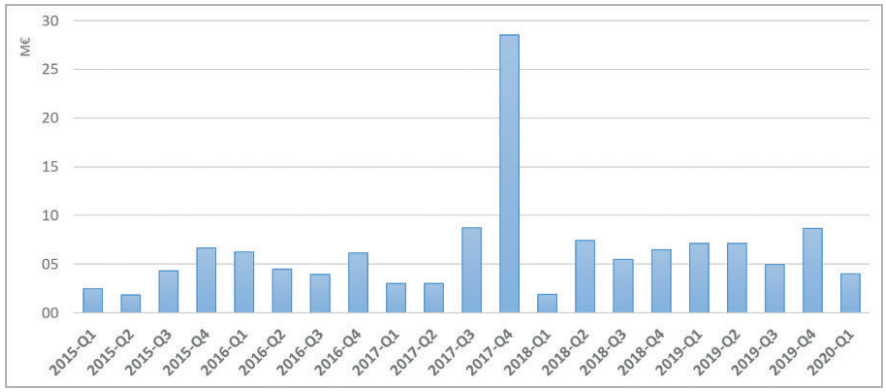

Figure 12 Distribution of funds to Polish entities divided by quarters of particular years
Source: European Space Agency report „Analysis of Industrial participation of Polish industry to ESA Programmes 2015-1Q2020"

The observed peak in Q4 2017 is related to three large contracts/ programmes: PLIIS: €14 million, DIAS: €13 million and JUICE/ Prodex: €8 million.

A total of €143 million (including PLIIS projects) has been contracted in Poland under ESA activities in the period from 2012 to the end of 2019.

Geographical return

The geographical return (GR) is the ESA Convention's regulated industrial policy for the European Space Agency. It is designed so that "all Member States participate in an equitable manner, with reference to their financial contribution, in the implementation of the European Space Programme and in the related development of space technologies". The return is measured by a coefficient,

calculated for each country, which is the ratio between the amount of contracts actually received and the expected value (the percentage of the Agency's funding multiplied by the total sum of the contracts awarded to all ESA members), taking into account the technological value of the contracts awarded.

The table below shows the level of geographical return over the years, divided by quarters and the rate of return in ESA's mandatory and optional programmes.

Year-quarter	GR - overall	GR Mandatory programmes	GR Optional programmes
2015-Q4	0.77	0.30	1.00
2016-Q1	0.86	0.59	1.03
2016-Q2	0.88	0.65	1.03
2016-Q3	0.90	0.65	1.07
2016-Q4	0.98	0.72	1.17
2017-Q1	0.96	0.69	1.17
2017-Q2	0.97	0.80	1.11
2017-Q3	1.05	1.00	1.10
2017-Q4	1.06	1.02	1.09
2018-Q1	1.02	1.02	1.03
2018-Q2	1.03	1.04	1.03
2018-Q3	1.05	1.06	1.04
2018-Q4	1.02	1.06	0.99
2019-Q1	1.03	1.09	0.98
2019-Q2	1.03	1.07	1.00
2019-Q3	1.04	1.11	0.98
2019-Q4	1.03	1.06	1.01
2020-Q1	0.71	0.07	0.98

Table 3 Level of geographical return (GR) over the years, divided by quarter and rate of return in ESA's mandatory and optional programmes
Source: own study based on European Space Agency report „Analysis of Industrial participation of Polish industry to ESA Programmes 2015-1Q2020"

As can be seen from the table above, in recent years the overall geographical return ratio has been achieved and even slightly above the ideal 1.0.

The decrease in geographical return in mandatory programmes in the first quarter of 2020 is due to the PLIIS dedicated programme for Polish entities, which ended in 2019. From 2020 onwards, Polish companies and scientific entities participate in tenders in mandatory programmes on an open basis, without the special preference of a dedicated programme.

Polish Industry Incentive Scheme (PLIIS)

A total of 487 applications from 145 Polish entities were submitted under PLIIS.

Phase	Final date for submission of offers	Number of offers received	Sum of budgets proposed in offers (in EUR)	Number of offers recommended for implementation	Success rate	Total recommended budget to be used as part of the PLIIS programme (in EUR)	Additional budget for the PLIIS programme (in EUR)	Program z którego dodatkowy budżet jest zapewniony
Pierwszy przetarg	01/05/2013	76	17,122,049	36	47%	6,791,379	98,686	TRP/EOP
Drugi przetarg	14/04/2014	70	13,119,915	28	40%	4,555,525	872,842	EOP
POC_TEB01	04/11/2015	32	9,015,838	12	38%	2,687,595		
POC_TEB02	04/02/2016	19	3,415,467	7	37%	1,350,111		
POC_TEB03	20/04/2016	14	2,570,732	6	43%	683,679		
POC_TEB04	29/07/2016	27	5,979,082	14	52%	3,715,972		
POC_TEB05	24/11/2016	38	8,302,302	20	53%	4,317,633		
POC_TEB06	08/02/2017	19	6,955,827	10	53%	3,032,224		
POC_TEB07	26/04/2017	17	2,984,283	4	24%	595,549		
POC_TEB08	26/07/2017	25	5,509,626	12	48%	2,199,571		
POC_TEB09	01/11/2017	30	7,466,601	10	33%	2,436,240	199,939	EOP
POC_TEB10/11	09/03/2018	33	6,668,730	10	30%	1,610,209		
POC_TEB12	08/11/2018	53	13,479,964	12	23%	2,788,955		
Total open tenders		453		181	40%	€34,328,402	€1,171,467	
Top-down action plans	-	22	-	17	-	5,823,154	100,000	SSA
Ad hoc actions	-	12	-	12	-	8,984,563	7,500,000	GSTP/SCI/EOP
Total		487	€102,590,416	210	43%	€49,136,119	€8,771,467	

Table 4 Details of the PLIIS ESA programme
Source: own study based on ESA report „End of Transition Measures Review Report for Poland".

The total amount based on the offers submitted under the PLIIS programme was 102 million € (double the total PLIIS budget) and the total amount of recommended actions is 58 million €, of which 49 million € is financed by the PLIIS[5] programme. This indicates a low level of co-financing from other programmes. Only specific ad hoc actions received significant co-financing from the GSTP, SCIENCE and EOEP programmes.

Among the contracts awarded, 65% are assessed as having a good chance of continuing work in ESA optional programmes (if funding is available) or in other activities, 12% have a moderate chance of doing so and 13% are at a stage too early for such an assessment. Therefore, only 10% of the activities funded by the PLIIS programme ended up as one-off activities or with no possibility of continuation. In ESA's opinion this is a very good result.

In projects where the TRL is known or has been measured, 92% achieved or exceeded the planned TRL, which is a very good result.

At the end of 2019, the status of the 204 PLIIS actions for which negotiations have at least started, together with the number of projects and the percentage in relation to the number of actions, was as follows:

- Closed projects: 98 (48% of the number of actions) - representing 36% of the total budget;
- Cancelled projects: 8 (3,9%);
- Ongoing projects (still in progress): 95 (46.6%);
- Waiting for the finalisation of the contract: 3 (1,5%).

At the end of Q1 2020, total industrial commitments amounted to €52 million.

[5] *The information in this subsection is based on surveys of stakeholders and the ESA report, End of Transition Measures Review Report for Poland.*

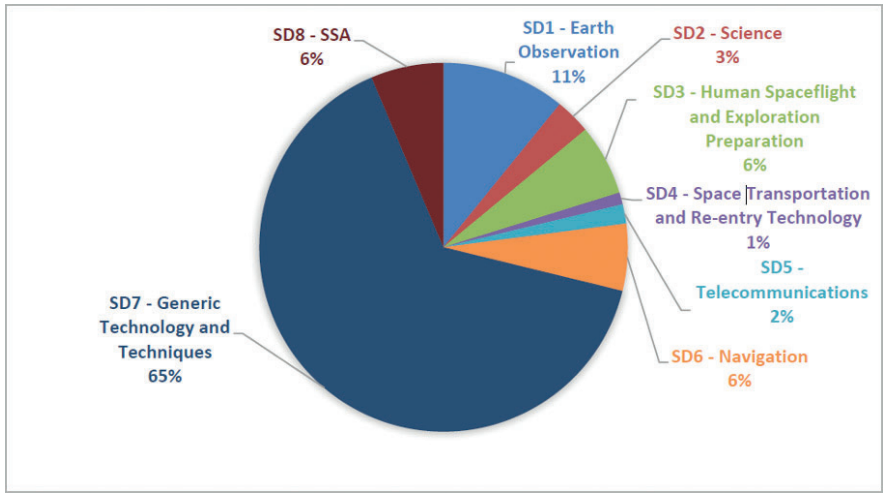

Figure 13 Breakdown of PLIIS projects according to ESA domains
Source: ESA

Projects in PLIIS are classified by type, where:

- Type (a) means high TRL, close to market, product or service-related activities (called „Flight");
- Type (b) means R&D activities with a medium TRL (typically 2-5);
- Type (c) means activities with a low TRL (called „preparatory");
- Type (d) means medium to high levels of TRL associated with application and service development.

The table below presents all 453 offers received under PLIIS programme. There is a clear predominance of R&D activities in all tenders. As expected, there is a shift from mainly preparatory activities in the first years, to R&D and finally to type a activities. This was also stimulated by additional restrictions introduced in the last two tenders in 2018:

- activities of type (d) were not allowed;
- preparatory activities for SSA or Prodex programmes were excluded;
- mechanism- and software-related activities were excluded.

In addition, the table details the breakdown into the above classification of all 181 projects recommended for implementation under PLIIS.

Phase	Typy oferty							
	(a) Flight		(b) R&D		(c) Preparatory		Applications and services	
	Offers received	Recom-mended for imple-mentation	Offers re-ceived	Recom-mended for imple-mentation	Offers received	Recom-mended for implemen-tation	Offers received	Recom-mended for implemen-tation
1st Call (2013)	6	2	41(54%)	17(50%)	17	11	12	4
2nd Call (2014)	2	1	47(67%)	20(69%)	9	2	12	6
TEB01 (2015)	5		21(66%)	9(75%)	2		4	2
TEB02 (2016)			10(53%)	5(71%)	3		6	2
TEB03 (2016)			8(57%)	3(75%)	2	1	4	
TEB04 (2016)	3	2	15(55%)	8(57%)	4	2	5	2
TEB05 (2016)	2	2	26(68%)	14(74%)	1		9	3
TEB06 (2017)	3	2	10(53%)	8(73%)	4	1	2	
TEB07 (2017)			11(65%)	5(83%)	4	1	2	
TEB08 (2017)	1	1	16(64%)	9(90%)	2	2	6	2
TEB09 (2017)	3		18(60%)	5(71%)	3		6	1
TEB10/11(2018)	2		19(58%)	7(70%)	8	1	4	2
TEB12 (2018)	10	3	37(70%)	8(67%)	6	1		
Total	37(8%)	14(8%)	279(62%)	121(67%)	65(14%)	22(12%)	72(16%)	24(13%)

Table 5 Breakdown of offers received and recommended for implementation under PLIIS divided by activity classification
Source: own study based on ESA report „End of Transition Measures Review Report for Poland".

In order to study the evolution of TRL level changes in PLIIS, data from completed projects were divided into three phases (Phases 1 and 2 and Phase 3, which includes top-down projects defined and executed within the roadmap):

- Phase 1, which covers a period of approximately three years (starting in 2013-2015¬) and included 42 completed actions from the first and second calls;
- Average TRL: initial = 2.4, target = 4.1, actual = 4.2;
- Ground : 3 projects have reached TRL 7 to 9[6];
- Space : 9 projects have reached TRL 4[7] ;
- Phase 2, which covers a period of approximately two years (starting in 2016-2017¬) and included 32 projects from open call TEB01 to TEB06;
- Average TRL: initial = 2.6, target = 4.5, actual = 4.4;
- Ground: 3 projects reached TRL 6 to TRL 7;
- Space: 3 projects achieved TRL 5, 3 projects achieved the result between TRL 6 and TRL 7;
- The next two points are called Phase 3:
- Ad hoc actions (only completed actions);
- Average TRL: initial = 3.4, target = 5.2, actual = 5.2;
- Space: 2 projects have reached TRL;
- Roadmap actions (no action yet completed): average: initial = 3.2, target = 6.1;
- Space: 5 projects should achieve TRL 7 or 8 .

The above-mentioned incomplete values of the TRL result from the obtained average of the projects. It should be noted that of the projects for which TRL is known/measured, 92% achieved or exceeded the planned TRL.

There is a clear increase in the TRLs achieved in phase 1 to phase 2. The ad hoc actions and roadmap projects from phase 3 were obviously at even higher TRL levels.

Ground activities, especially in the area of software and end-use applications, quickly reached the level of TRL 6 and above.

Eight space hardware/software (space) activities have so far achieved TRL 5 and above.

[6] *Ground - activities that have an earthly purpose.*

[7] *Space - activities ultimately intended for on-orbit applications, e.g. space hardware/software.*

Horizon 2020

In 2014-2019, i.e. since the beginning of Horizon 2020, in the space competitions to date, 35 Polish beneficiaries have obtained €12.75 million in funding as part of 39 projects, five of which are coordinated by Polish units.

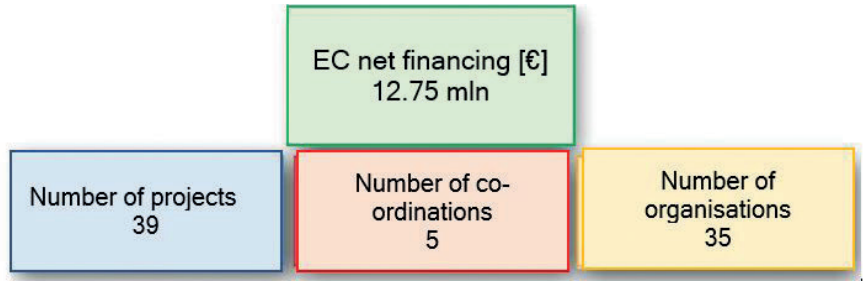

Figure 14 Participation of Polish entities in Horizon 2020 projects
Source: own study based on eCORDA databases as of 06.04.2020

Compared to all EU countries, in the 7th Framework Programme (FP7), Poland has moved from the 14th to the 12th position in terms of co-financing. Moreover, our country is an unquestionable leader among all the EU13 countries - over 37% of EC co-financing as part of the competitions in the H2020 space area is allocated to Polish beneficiaries. This is also a significant increase in comparison to the previous framework programme.

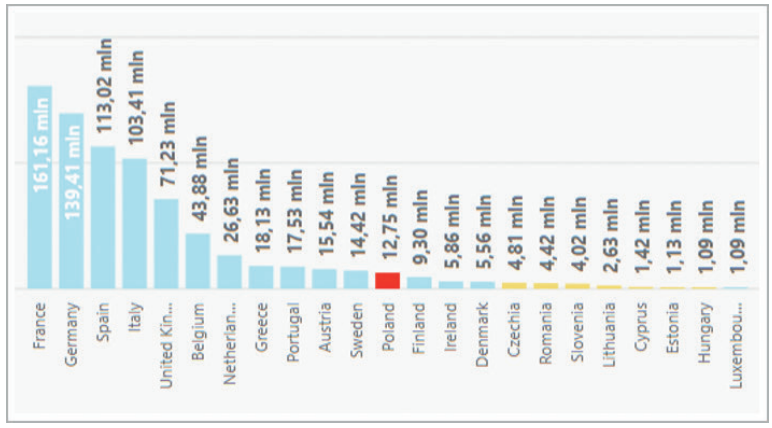

Figure 15 Net funding received [million €] from EU countries for Space projects
Source: NCP's study

One can also observe a significant increase in the share of Polish enterprises in both project applications submitted and projects implemented in comparison with FP7. Nearly 35% of the total co-financing is intended for enterprises. Five projects are coordinated by Polish enterprises, which constitutes 21.74% of all coordinated projects in the group of the so-called thirteen countries. More than € 0.7 million was obtained by enterprises under the SME Instrument. The percentage distribution of co-financing for particular types of implemented projects is largely balanced for individual instruments.

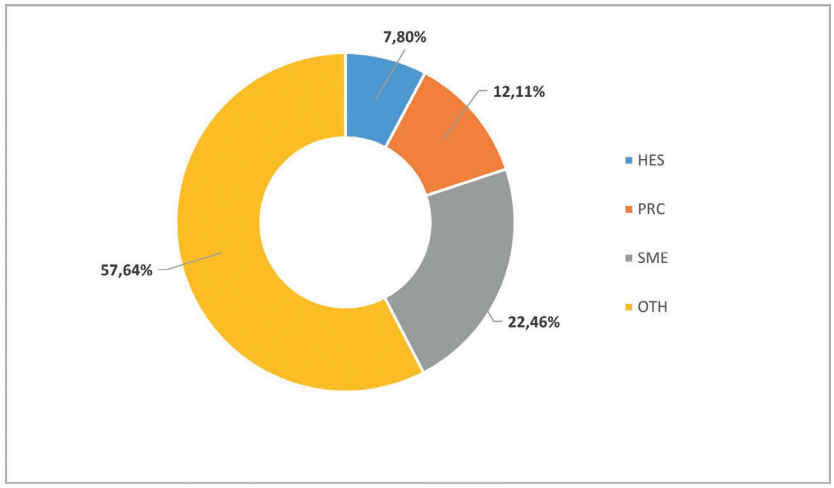

Figure 16 Organisational structure of projects implemented by Polish beneficiaries
Source: own study based on EU RP NCP

The example of the space area clearly shows the importance of the role of active participation of public administration in H2020. Noteworthy is one type of agreement for the implementation of a project co-financed by H2020 funds, SGA-RIA (Specific Grant Agreement - Research and Innovation Action), under which the Polish Space Agency obtained 5.2 million € funding. The activity of POLSA in H2020 should be emphasized - the Agency is involved as a partner in four projects. In total, POLSA has raised more than €6 million of co-financing, which is nearly 50% of the total Polish co-financing in the field of space as part of H2020. In the ranking of all beneficiaries from the EU countries participating in competitions concerning space technologies, POLSA was ranked at the 14th position, and thus it is among the key entities obtaining co-financing from the programme in this thematic area.

Name of the beneficiary	No. of coordinations	No. of particip.	Net EC funding (€)	% of EU budget
[DE] DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV	11	54	47 730 867,36	5,84%
[FR] CENTRE NATIONAL D'ETUDES SPATIALES - CNES	0	20	27 234 044,42	3,33%
[ES] CENTRO PARA EL DESARROLLO TECNOLOGICO INDUSTRIAL.	1	10	22 692 253,25	2,77%
[FR] THALES ALENIA SPACE FRANCE SAS	14	40	15 923 150,34	1,95%
[IT] AGENZIA SPAZIALE ITALIANA	2	11	12 955 676,96	1,58%
[UK] UK Space Agency	0	9	12 097 063,65	1,48%
[DE] AIRBUS DEFENCE AND SPACE GMBH	5	22	10 635 114,28	1,30%
[FR] CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	2	39	9 179 273,65	1,12%
[BE] SPACE APPLICATIONS SERVICES NV	6	12	8 691 485,25	1,06%
[DE] FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWA...	1	17	7 364 244,75	0,90%
[IT] THALES ALENIA SPACE ITALIA SPA	2	22	6 657 582,00	0,81%
[FR] COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTE...	2	12	6 449 081,60	0,79%
[ES] GMV AEROSPACE AND DEFENCE SA	6	12	6 258 172,25	0,77%
[PL] POLSKA AGENCJA KOSMICZNA	0	4	6 077 917,50	0,74%
[FR] OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES	3	10	5 906 961,98	0,72%

Figure 17 Ranking of key European entities implementing H2020 space projects
Source: NCP's study based on data from the European Commission

Polish Space Agency participates in system projects for three flagship space programmes of the European Union (Space Situational Awareness, Secure Satellite Communication, Space Robotics). Within the system of observation and tracking of objects in space, the task of POLSA is to build a network on the basis of existing telescopes and to develop this infrastructure for the needs of the national operational centre, which will have the capacity to identify and observe objects moving in orbit around the Earth. More than 70% of the value of the POLSA grant awarded goes to the national companies and scientific entities involved in building the network. In turn, the Secure Satellite Communication Programme is a new programme. The participation of representatives of the national administration at such an early stage of the programme development will make it possible to ensure future adequate participation of Polish entities in this important area. In the project called Strategic Research Cluster in Space Robotics with the acronym PER ASPERA, the Polish Space Agency has been participating for a short time (formally since the beginning of 2019). This should lead to increased participation of national entities in EC R&D projects in this area.

In Annex 2, the table lists space-related projects as part of H2020 in which Polish entities participated.

European GNSS Agency (EUSPA)

The European GNSS Agency manages the European satellite navigation programmes - Galileo and EGNOS. In addition, EUSPA offers grant programmes. Grants are direct financial contributions for activities that lead to the achievement of an objective that is part of a European Union policy.

In accordance with the Delegation Agreements of the European Commission, EUSPA may award grants funded under the GNSS and H2020 programmes. Each year, EUSPA publishes an annual grant plan with objectives, a timetable for calls for proposals with indicative amounts and expected outcomes and criteria. To date, 12 contracts have been awarded to Polish entities under EUSPA grants for a total amount of €2.075 million. In addition to grants, the Agency also offers public procurement for the implementation of space projects.

European Southern Observatory (ESO)

Poland became the 15th member of ESO on the 28th of October 2014. The Ministry of Education and Science is responsible for the coordination of membership in this organisation. Poland's current annual contribution to the organisation is 3.06% of its revenue, i.e. €4,971 million. The contribution of a member country is calculated on the basis of net national income.

ESO works with industry to design and build instruments and telescopes, including the Extremely Large Telescope (ELT), the world's largest telescope to be built in the next few years.

ESO does not apply the principle of geographical return, as is the case in ESA. Cooperation between ESO and industry aims to achieve the best possible results while maintaining acceptable costs. The tender procedure is competitive and, where possible, is carried out in ESO Member States. The ESO Industrial Liaison Officer (ILO) plays an important role in shaping the industrial policy of ESO Member States, with the task of following up ESO tenders and informing potentially interested companies in the country about them, as well as providing such information to ESO at an early stage of the tender process.

Since the beginning of Poland's membership in ESO, national companies have executed contracts for a total amount of € 16 052 112. There are 49 Polish entities registered in the ESO tender database.

EUMETSAT

Poland established relations with EUMETSAT in 2000 as a cooperating member, and gained full membership in 2009. The Ministry of Infrastructure is responsible for all relations with the organisation, on behalf of which the Institute of Meteorology and Water Management - PIB - participates in the work of EUMETSAT bodies. Data received from EUMETSAT are primarily used by national hydrological and meteorological services for forecasting, hydro-meteorological protection of society and economy, as well as by the Polish Armed Forces, universities and research institutes. Other potential applications of images from meteorological satellites are as follows: agriculture, forestry, spatial management, investment planning, monitoring of water areas (including the Baltic Sea) and the atmosphere, including among others the study of the level of trace gases and aerosols.

EUMETSAT currently owns meteorological satellites and operates data distribution services for several satellite missions. The most important EUMETSAT programmes are MSG (Meteosat Second Generation) and EPS (Eumetsat Polar System). These are mandatory programmes and Poland participates in both. Further continuations of these programmes are currently being prepared, i.e.: Meteosat Third Generation, which consists of satellites in geostationary orbit providing images of the entire hemisphere and data for short-term weather forecasts, and EPS Second Generation (EPS-SG), which will consist of a constellation of two satellites orbiting the polar orbits (in total, three sets of two satellites will be used during the programme).

EUMETSAT is also involved in the Copernicus Programme as this organisation operationally exploits and distributes data and products from Sentinel-3. In addition, EUMETSAT will acquire data from Sentinel-4 and Sentinel-5 satellites. Sentinel-6/Jason-CS, on the other hand, is operated by EUMETSAT in cooperation with ESA, CNES, NASA, NOAA and EC. EUMETSAT also collaborates with

meteorological services from some EUMETSAT Member Countries through a network of Satellite Application Facilities (SAFs) which are part of the ground segment.

EUMETSAT works in close cooperation with the European Space Agency. The ESA is responsible for the construction and delivery of the space segment, while EUMETSAT is responsible for the launch, construction of the ground segment and maintenance of the mission operation, in particular acquisition, collection, processing of satellite data necessary for weather forecast, tracking of environmental and climate change. The ESA contributes substantially (70%) to the development costs of the first of a series of satellites under its optional programme and leads the procurement process for the other satellites on behalf of EUMETSAT. The organisation contributes a fixed share (30%) of the development costs for the first satellite in the series and fully covers the development costs for the other satellites.

At present, the greatest opportunities for EUMETSAT contracts are in the areas of big data and the development of applications using data from EUMETSAT meteorological satellites. These are the areas in which EUMETSAT tenders are most frequently published on a dedicated platform (EUMITS). This situation creates opportunities for the IT sector. The organisation's industrial policy is based on the selection of project contractors in a competitive tender procedure and the evaluation of offers is carried out according to the criterion of best value for money. It should be emphasised that EUMETSAT, unlike ESA, does not apply the geographical return principle ("geo-return").

The value of contracts with EUMETSAT to date includes approximately 10 projects totalling just under €5 million. There are 58 industrial entities from Poland registered in the EUMETSAT tender database. Projects implemented by Polish entities for the EUMETSAT organisation are dominated by a significant contract signed in April 2019 and implemented by a Polish company in cooperation with foreign partners. The contract, the value of which exceeds €10 million (including €4.7 million for the Polish partner), concerns the creation and maintenance of one of the five European DIAS (Data and Information Access Services) platforms for the

EUMETSAT, ECMWF and Mercator consortium. It is the second of all five DIAS platforms to be provided by Polish companies. It provides services for environmental data, its remote processing and specialised support for end users. The platform under development will enable access to information collected by Copernicus Sentinels, other satellites and the so-called Copernicus Services, which process satellite data for use in selected areas such as water, land, atmosphere or climate change monitoring.

The EUMETSAT National Focal Contact Point within the Polish Space Agency's organisational structure plays an important role in supporting the national space industry's cooperation with EUMETSAT. The role of the National Focal Contact Point is to follow EUMETSAT calls for tenders and to inform potentially interested companies in the country about EUMETSAT calls for tenders, and to forward this information to EUMETSAT at an early stage of the call for tenders.

d. Technological domains developed in the Polish space sector

To ensure clarity of the required technological solutions and to facilitate technology harmonisation, the European Space Agency has divided space sector issues into 26 technology domains (Table 1). The ESA technology tree is designed to help experts participating in IPC THAG (Industrial Policy Committee, Technology Harmonization Advisory Group) meetings in setting specific directions for the space industry and describing the current state of technology.

The domains developed by ESA are divided into sub-domains that treat in detail the problems related to the development of the space industry. The latest version of the Technology Tree is from 2020. (ESA Technology Tree, Version 4.0, reference: STM-277 3rd ed.).

The breakdown of technology domains in the above-mentioned document is as follows:

Tech. domain no. (TD)	Name	Description
1.	On-Board Data Systems	Systems for processing, storing and managing spacecraft and payload data, equipment and software necessary for data acquisition, management of the network layer
2.	Space System Software	Systems addressing both space and ground stations, all major software and information technology techniques and technologies with regard to their application to space missions, applications using satellite data, collection, processing and archiving of large scale data
3.	Spacecraft Electrical Power	Technologies related to electromagnetic system architectures, power generation, storage, distribution and air conditioning systems
4.	Space Environments & Effects	A section describing the constraints arising from the characteristics of the space environment for space missions, the requirements necessary for designing mission elements, performing measurements and -tests
5.	Space System Control	Technologies related to the control of space mission systems, both for the space part and the ground segment
6.	RF Payload and Systems	Includes satellite system and network technologies , payloads, ground equipment for telecommunications, TT&C, navigation, Earth observation, microwave and millimetre wave frequencies
7.	Electromagnetic Technologies & Techniques	Antennas and related technologies, interaction and propagation of waves, electromagnetic compatibility
8.	System Design & Verification	Technologies related to characterisation, design and testing of space systems; activities focus on reducing development time of new technology and production costs; risk control and work progress
9.	Mission Operation & Ground Data systems	Control and use of space and ground systems. The domain also describes technologies and supporting tool, focuses on Mission Control System (MCSs)
10.	Flight Dynamics & GNSS	Analysis of the space mission in terms of trajectory, operational (ground) analyses related to flight and object orbit measurements and control

Tech. domain no. (TD)	Name	Description
11.	Space Debris	Includes technological and scientific information related to meteoroids and space debris, their impact on spacecraft, risk assessment and protection against such events, deorbiting space objects
12.	Ground Station System & Networks	Standards and knowledge of engineering solutions connecting the space segment with the control centre (ground segment)
13.	Automation, Telepresence & Robotics	Includes standardisation, development, testing, use and disposal of robotic systems. Such systems include, among other things, robotic booms, spacecraft interior robotic systems associated with payloads, mobile exploratory robots, automated laboratories
14.	Life & Physical Sciences	Technologies related to scientific research carried out by/on space objects, provision of complete testing systems, bringing samples down to earth, protection of the space environment, control of ongoing research
15.	Mechanisms & Tribology	Devices requiring the movement of one or more components, e.g. control mechanisms, actuators, etc., and systems for simulating mechanical systems
16.	Optics	Optical instruments, design, manufacturing and testing processes
17.	Optoelectronics (optoelectronics)	Production and development of optoelectronic components/devices
18.	Aerothermodynamics (aerodynamics)	Domain dedicated to aerodynamics and aerothermodynamics, including high temperature chemical kinetics, gas-surface interactions, analysis of advanced flow control systems
19.	Propulsion	Spacecraft propulsion processes and technologies, chemical and electric propulsion and advanced non-classical methods
20.	Structures & Pyrotechnics	Technologies and methods related to design, analysis, production and testing of materials/structures, degradable, highly stable and strong structures, hot structures, shields against meteorite and space debris impacts, pyrotechnic components

Tech. domain no. (TD)	Name	Description
21.	Thermal	Technologies related to thermal control
22.	Environmental Control Life Support (ECLS) & In Situ Resource Utilisation (ISRU)	Systems to facilitate and enable human existence in space and to exploit local resources
23.	EEE Components and quality	Includes design, manufacturing and testing of electronic components (electrical, electromechanical and electronic EEE), requirements for use of these components in on-board systems
24.	Materials and Processes	Discusses the physicochemical characteristics of materials, materials mechanics and manufacturing processes, non-destructive testing, terrestrial and space effects on materials, additive manufacturing, and composite materials
25.	Quality, Dependability and Safety	Includes topics related to requirements, liability, contingency, availability and safe use of space systems, space mission risk management systems
26.	Other	Subject matter not falling within any of the above domains, i.e. constellations - meteorology, micro- and nano- technologies as well as ground applications using satellite data

Table 6 Technology domains of the European Space Agency
Source: http://www.esa.int/Our_Activities/Space_Engineering_Technology/Technology_Domains

Materials about technological development broken down into individual domain and sub-domain from ESA's technology tree, including a technical dossier and roadmap, are helpful for both those experienced in the space industry and beginners. They provide an overview of prevailing market trends and ESA's plans in relation to the technologies in question.

Familiarity with the technology domains proposed by ESA, in relation to which the documents are developed, allows a skilful advice to entrepreneurs and institutions on the current market situation, as well as a familiarisation with the technology used in space missions and with the requirements, procedures, systems and technological processes involved. In addition, it gives the opportunity to broaden the knowledge with scientific aspects.

From the point of view of technological development, the ESA Polish Industry Incentive Scheme (PLIIS), implemented in 2012-2019, was the most significant for Polish entities.

I. Polish Industry Support Programme (PLIIS) - summary

A total of 487 applications from 145 Polish entities were submitted under PLIIS. 210 actions were recommended for implementation (including ad hoc actions and top-down action plans).
Details of the PLIIS are shown in the table below:

Recruitment number	Date of recruitment	Number of offers received	Budget of the proposed offers (in EUR)	Number of approved projects	Success rate	Budget from PLIIS programme (in EUR)
First tender procedure	01/05/2013	76	17,122,049	36	47%	6,791,379
Second tender	14/04/2014	70	13,119,915	28	40%	4,555,525
POC_TEB01	04/11/2015	32	9,015,838	12	38%	2,687,595
POC_TEB02	04/02/2016	19	3,415,467	7	37%	1,350,111
POC_TEB03	20/04/2016	14	2,570,732	6	43%	683,679
POC_TEB04	29/07/2016	27	5,979,082	14	52%	3,715,972
POC_TEB05	24/11/2016	38	8,302,302	20	53%	4,317,633
POC_TEB06	08/02/2017	19	6,955,827	10	53%	3,032,224
POC_TEB07	26/04/2017	17	2,984,283	4	24%	595,549
POC_TEB08	26/07/2017	25	5,509,626	12	48%	2,199,571
POC_TEB09	01/11/2017	30	7,466,601	10	33%	2,436,240
POC_ TEB10/11	09/03/2018	33	6,668,730	10	30%	1,610,209
POC_TEB12	08/11/2018	53	13,479,964	12	23%	2,788,955
Total open tenders		453		181	40%	€34,328,402
Top-down action plans	-	22	-	17	-	5,823,154
Ad hoc actions	-	12	-	12	-	8,984,563
Total		487	€102,590,416	210	43%	€49,136,119

Table 7 Details of the PLIIS ESA programme
Source: own study based on ESA report "End of Transition Measures Review Report for Poland".

The table below, based on projects carried out under the Polish Industry Incentive Scheme, presents the number of individual projects, including completed and ongoing projects, divided by technological domains.

Technology domain name	Number of projects under PLIIS		
	Com-pleted	Ongoing	Total
TD1 On-board Data Systems	4	8	12
TD2 Space System Software	17	10	27
TD3 Electrical Power	3	3	6
TD4 Spacecraft Environment & Effects	1	1	2
TD5 Space System Control	0	0	0
TD6 RF Payload	20	14	34
TD7 Electromagnetism Technologies & Techniques	3	1	4
TD8 System Design & Verification	10	3	13
TD9 Mission Operations & Ground Data Systems	12	4	16
TD10 Flight Dynamics & GNSS	3	0	3
TD11 Space Debris	6	13	19
TD12 Ground Station System & Networks	0	0	0
TD13 Automation, Telepresence & Robotics	4	2	6
TD14 Life and Physical Sciences	2	0	2
TD15 Mechanisms	10	9	19
TD16 Optics	2	3	5
TD17 Optoelectronics	0	0	0
TD18 Aerothermodynamics	0	0	0
TD19 Propulsion	4	10	14

Technology domain name	Number of projects under PLIIS		
	Com-pleted	Ongoing	Total
TD20 Structures & Pyrotechnics	2	5	7
TD21 Thermal	2	0	2
TD22 Environmental Control Life Support	0	0	0
TD23 EEE Components	1	0	1
TD24 Materials & processes	1	10	11
TD25 Quality, Dependability & Safety	1	1	2

Table 8 Number of individual PLIIS projects, including completed and ongoing ones, divided by technology domains
Source: ESA report of 17.06.2020 entitled "End of Transition Measures Review Report for Poland". (Ref ESA-IPLIPS-PL-2020-001)

The above summary shows that in terms of the number of PLIIS projects, the most important technology domains include:
1. On-board radio communication systems (34 projects);
2. Software for space systems (27 projects);
3. TD19 Mechanisms (19);
4. Space debris (19);
5. TD9 Ground data systems and mission operations (16);
6. TD19 Propulsion (14);
7. TD8 Systems design and verification (13);
8. On-board data systems (12);
9. TD24 Materials and Processes (11).

The value expressed in percentage of individual projects carried out by Polish entities in the PLIIS programme, divided by technological domains, is presented in the diagram below.

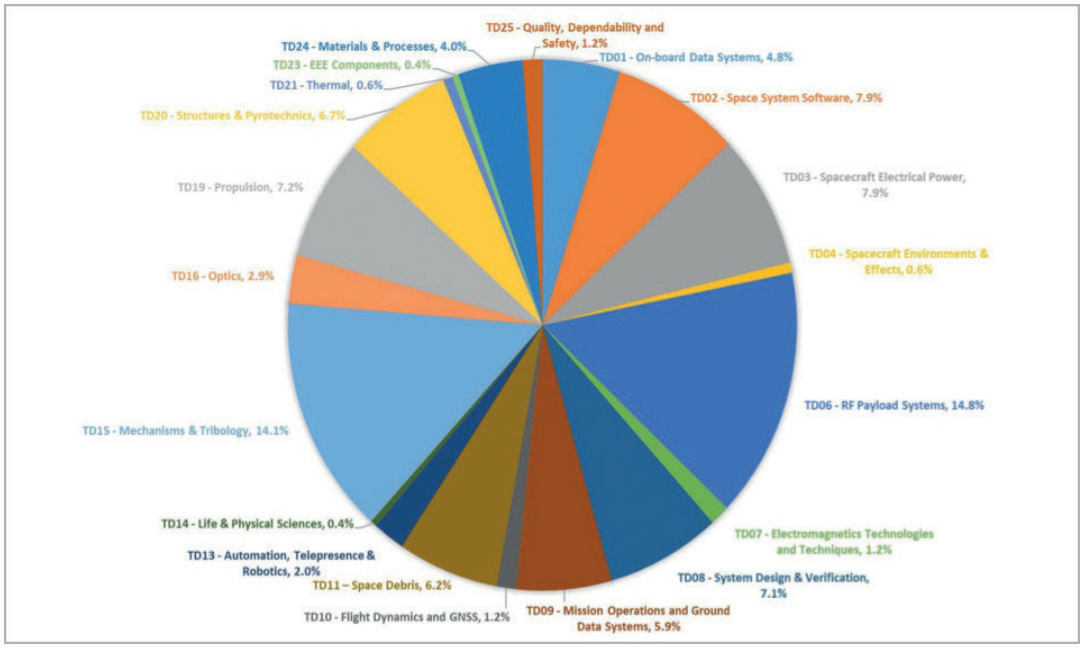

Figure 18 Percentage value of individual projects carried out by Polish entities in the Polish Industry Incentive Scheme, divided by technological domains
Source: ESA report of 17.06.2020 entitled "End of Transition Measures Review Report for Poland".

From the above division, it can be concluded that in terms of projects' value, TD6 (RF Payload Systems) and TD15 (Mechanisms) domains are the dominant technological areas in which activities are carried out under this most important ESA programme dedicated to Polish entities so far. Their percentage share in the PLIIS programme value amounts to 14.8% and 14.1% respectively.

The Software domain, both volatile and ground-based, is also of great importance. Projects using software can be found in several domains, such as:

- Software for space systems (7.9%);
- Space debris (6.2%);
- Ground data systems and mission operations (5.9%);
- On-board data systems (4.8%).

Other noteworthy technology domains include: Propulsion (7.2%), Structures and Pyrotechnics (6.7%), Systems Design and Verification (7.9%), Spacecraft Electrical Power (7.9%), although only six projects were recorded in the latter domain.

The chart below shows the maximum TRL value achieved in each domain in the PLIIS programme.

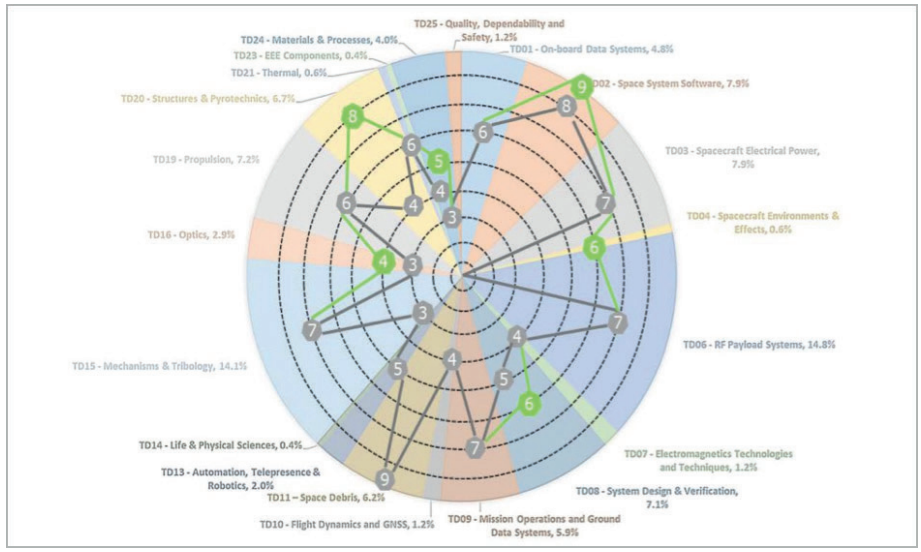

Figure 19 Maximum TRL value reached in each domain in the PLIIS programme
Source: ESA report of 17.06.2020 entitled "End of Transition Measures Review Report for Poland".

It is noteworthy that TRL 6 readiness level has already been achieved in nine areas, i.e.:

- On-board radio communication systems;
- Mechanisms;
- Space debris;
- Systems design and verification;
- Ground data systems and mission operations;
- Software for space systems;
- Electrical power supply for spacecraft;
- Structures and pyrotechnics;
- Propulsion.

The highest TRL level achieved to date concerns the domains of Software for Space Systems, Space Debris and Structures and Pyrotechnics.

The diagram below presents the share of each technology domain in the period between 2015 and Q1 2020 in a broader context, i.e.

taking into account not only the PLIIS programme but also all other ESA's programmes, including optional and mandatory programmes.

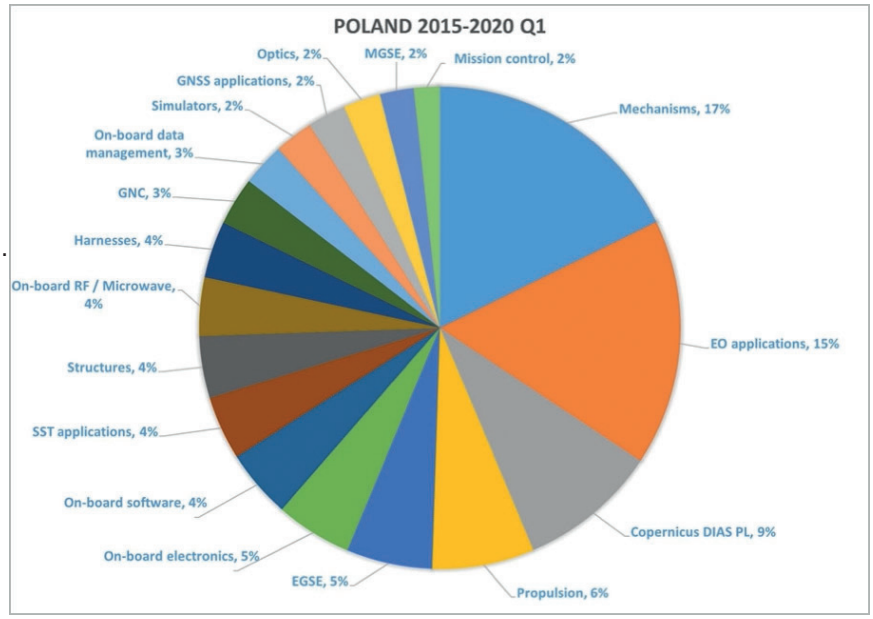

Figure 20 Share of each technology domain in 2015Q1 2020 in all ESA's programmes
Source: ESA report of 01.10.2020 titled "Analysis of Industrial participation of Polish industry to ESA Programmes 2015-1Q2020".

The chart shows that the largest share in terms of value was accounted for by projects assigned to the following domains and services: mechanisms (17% of the value of all contracts), applications using data from Earth observation programmes (15%), services with management, archiving and processing of large-scale data (9%), and propulsion (6%).

II. Technology domains according to a survey conducted by POLSA in 2020.

In the first half of 2020, DSWM staff joined, together with the European Space Agency, a survey regarding the potential of the Polish space sector. As a result of this cooperation, a sector survey questionnaire was developed and submitted for evaluation to the POLSA Council on the 13th of February 2020. After taking into account the comments of the Council, the survey was sent to the entities of the Polish space sector - 75 enterprises and 23 scientific entities, in total 98 entities.

The survey contained substantive sections such as financial data, products and services offered by the entity in the space sector, planned development of space technologies by the entity with a description of the investments already made in these areas, a description of the entity's organisation, the entity's strategy in the space sector, the laboratory, test and production infrastructure available in the organisation and locally, including a description of the problems involved.
Responses were obtained from 50 entities, i.e. 42 companies and 8 scientific and research units. The data illustrate the status at the end of 2019.

The table below presents the results of the questionnaires regarding the point concerning the technologies developed by the entities according to the so-called ESA technology tree. It should be noted that within one domain, some entities develop even several technologies corresponding to particular sub-domains.

The table shows the number of domains under development broken down by the current TRL level, as well as the total number within domains from 1 to 26. The results are not fully reliable as not all entities that received the survey completed it. The table should be considered as supporting and supplementary material.

Technology domain name	TRL 1- TRL 4	TRL 5 – TRL 7	TRL 8 – TRL 9	Total
TD1 On-board Data Systems	4	5	3	12
TD2 Space System Software	10	13	8	31
TD3 Electrical Power	1	1	4	6
TD4 Spacecraft Environment & Effects	0	0	1	1
TD5 Space System Control	4	3	1	8
TD6 RF Payload	6	7	3	16
TD7 Electromagnetism Technologies & Techniques	2	1	3	6
TD8 System Design & Verification	1	4	2	7
TD9 Mission Operations & Ground Data Systems	2	1	1	4
TD10 Flight Dynamics & GNSS	2	2	0	4
TD11 Space Debris	5	2	1	8
TD12 Ground Station System & Networks	2	1	0	3
TD13 Automation, Telepresence & Robotics	4	2	1	7
TD14 Life and Physical Sciences	0	0	1	1
TD15 Mechanisms	8	9	5	22
TD16 Optics	4	1	1	6
TD17 Optoelectronics	3	3	1	7
TD18 Aerothermodynamics	1	2	0	3
TD19 Propulsion	11	5	2	18
TD20 Structures & Pyrotechnics	4	5	4	13

Technology domain name	TRL 1- TRL 4	TRL 5 – TRL 7	TRL 8 – TRL 9	Total
TD21 Thermal	3	2	1	6
TD22 Environmental Control Life Support	0	0	0	0
TD23 EEE Components	3	0	4	7
TD24 Materials & processes	2	3	2	7
TD25 Quality, Dependability & Safety	0	0	1	1
TD 26 Others	0	0	0	0

Table 9 Number of domains under development divided by current TRL level, and total number within domains 1 to 26
Source: own study

Based on the above list, the next chart shows the ESA technology domains most widely used and most frequently declared in entities' surveys:

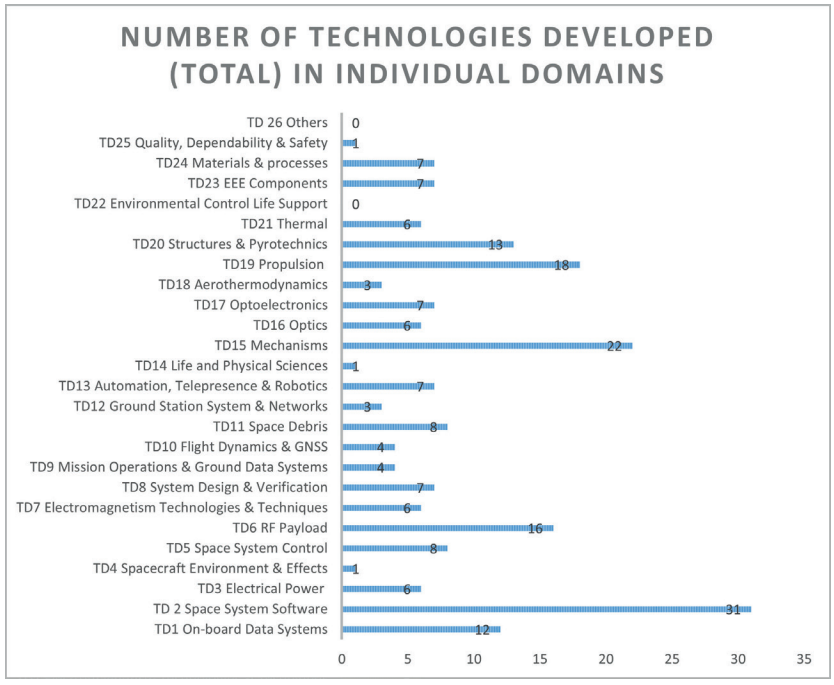

Figure 21 ESA technology domains the most widespread and most frequently declared in the surveys
Source: own study

According to the surveyed 50 entities of the space sector, the following domains are the most represented:

- TD 2 - Space software (31 statements);
- TD 15 - Mechanisms (22 declarations);
- TD 19 - Propulsion (18);
- TD 6 - On board radio communication systems (16);
- TD 20 - Structures and Pyrotechnics (13);
- TD 1 - On-board data systems (12).

In terms of the readiness level from TRL 5 to TRL 7, the number of technologies developed by the surveyed entities is as follows:

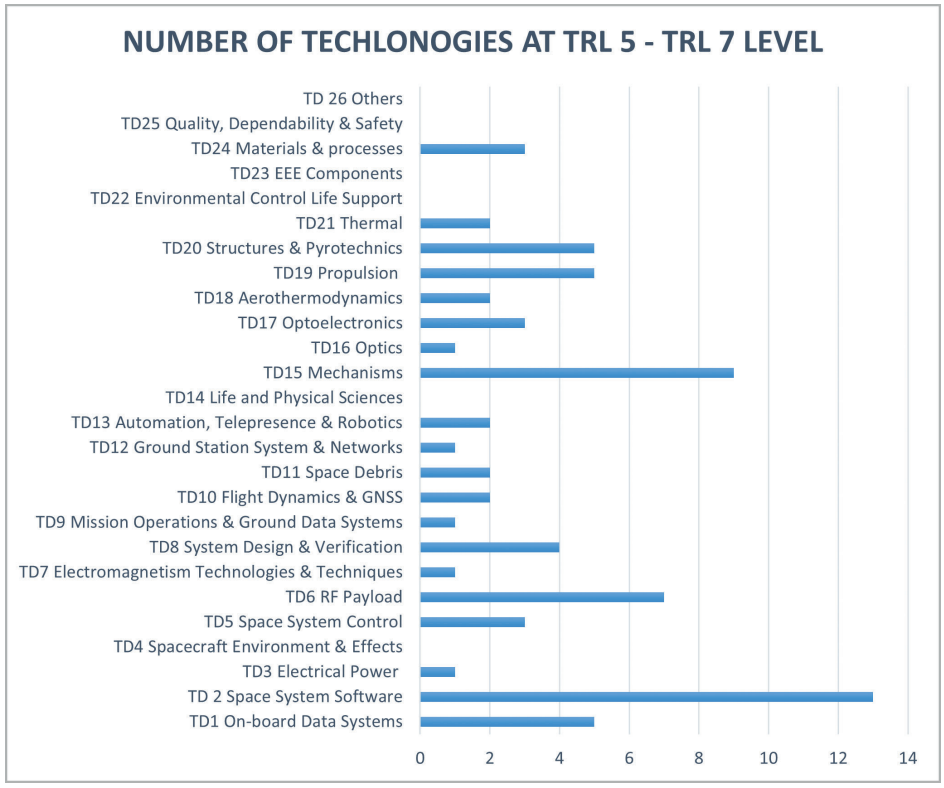

Figure 22 Number of technologies developed by the surveyed entities in the field of readiness level from TRL 5 to TRL 7
Source: own study

In turn, the number of technologies developed by the surveyed entities with the highest level of development, i.e. readiness levels from TRL 8 to TRL 9, is as follows:

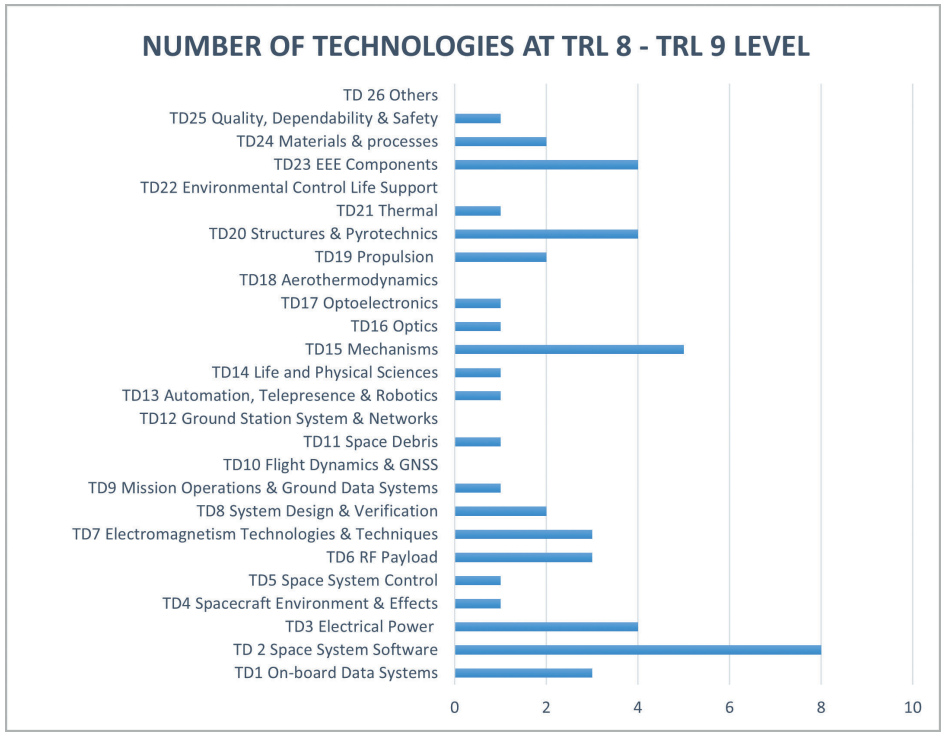

Figure 23 Number of technologies developed by the surveyed entities in the field of readiness level from TRL 8 to TRL 9
Source: own study

III. Technological domains developed by Polish entities as part of the European Union's research and development programme - Horizon 2020 and by the National Centre for Research and Development

Project title	Start date	Completion date	Techno-logical domain
Hybrid Propulsion Module for transfer to GEO orbit	01.02.2015	31.01.2018	TD19
Advanced Concept for laser uplink/ down-link CommuniCation	01.06.2015	30.09.2017	TD17
Demonstrator of EGNSS Services based on Time Reference Architecture	01.01.2015	31.12.2016	TD10
E-GNSS Knowledge Triangle	01.01.2015	31.05.2018	TD10
First European System for Active Debris Re-moval with Nets	01.04.2015	30.09.2017	TD 11, TD 15
Wytwarzanie wysoko skoncentrowanego nadtlenku wodoru (HTP)	01.03.2015	31.05.2015	TD19
Zintegrowany pakiet czujników 3D do eks-ploracji robotycznej	01.11.2016	31.01.2019	TD13
Budowa szybkich konwerterów danych no-wej generacji	01.12.2016	30.09.2021	TD2
Roboty planetarne wdrożone do zadań montażowych i konstrukcyjnych	01.02.2019	31.12.2021	TD13
Technologie serwisowania satelitów przy użyciu systemów robotycznych	01.02.2019	31.01.2021	TD13
Galileo dual frequency, 5G, IoT devices and services for Drones, Assets Management and Elite sport	01.12.2019	31.05.2021	TD6
The NEO Rapid Observation, Characteriza-tion and Key Simulations	01.01.2020	30.06.2022	TD11

Table 10 Technological domains developed by Polish entities under the European Union research and development programme Horizon 2020
Source: own study

Over the last five years, more than 40 projects have been financed from these instruments. They were used by companies as well as universities and research institutes. The list of such projects can be found below. They relate to both space exploration and exploitation, as well as the use and processing of satellite data and the development of end-user applications in many ground application areas, such as transport and telecommunications, environment, health and agriculture.

The list of selected projects regarding generic technologies financed by the National Centre for Research and Development according to technological domains from the so-called ESA technology tree is presented below:

Project title	Start date	Completion date	Techno-logical domain
"Lightweight nanocrystalline aluminium-based material for space applications (modelling and technology verification) LI- GHTMAT4SPACE"	01.12.2015	30.11.2017	TD 24
"Development and validation of a satellite manipulator control system"	01.01.2020	31.12.2021	TD 5
"Specialised hybrid rolling bearings for aerospace applications"	01.11.2012	30.04.2015	TD 15
"New advanced Al-Ti sandwich materials with improved ballistic resistance for aerospace structures"	01.11.2013	31.12.2016	TD 24
"Development of a technology for high--pressure gas quenching of satellite gears of an epicyclic FDGS aircraft engine transmission, made of steel and operating under long-term and cyclically variable service loads"	01.02.2020	31.01.2023	TD 15/ TD 19
"Development of technology for large-area autonomous gas detectors of ionising radiation, including cosmic radiation"	01.11.2016	31.01.2020	TD 4
"Development of a multifunctional enclosure for space and aerospace electronics with special focus on the so-called power electronics and power sources"	01.11.2017	31.10.2018	TD 20

Project title	Start date	Completion date	Techno-logical domain
"An intelligent on-board computer for nano- and microsatellites with improved reliability and increased computing power, allowing self-diagnosis of the satellite in orbit using machine learning algorithms for anomaly detection"	01.05.2020	31.12.2023	TD 1
"ASTRO-MODULES - Set of functional blocks -for small and medium satellites"	01.01.2020	31.12.2022	TD 15
"Development of a pioneering multifunctional 3D printing robot using an integrated robotic arm to achieve strength in printed models for use in the arms, aerospace and defence industries"	03.04.2018	31.12.2020	TD 15
"Development of an ultralight support structure for a 100 kN rocket motor assembly for space applications"	2020	b.d.	TD 15/ TD19
"Development and field testing of an in-orbit control and attitude control module for observation microsatellites"		b.d.	TD 5
"Temperature memory coatings for space technology research and development"		b.d.	TD 24
"Pulsed plasma propulsion for nano- and microsatellites"		b.d.	TD 1
"Preparation and production of innovative software for efficient, accurate astrometry and photometry of point and streak sources for astronomical CCD and CMOS cameras"		b.d.	TD 2
"Improving the technological readiness of S- and X-band communication system products/components"		b.d.	TD 6

Table 11 List of selected generic technology projects financed by NCRD according to technology domains from the so-called ESA technology tree
Source: own study

On the basis of the above statement, the following summary can be made regarding the number of technologies developed by Polish entities under the NCRD and EU Horizon 2020 programmes concerning generic technologies:

Technology domain name	TRL 1- TRL 4
TD1 On-board Data Systems	2
TD2 Space System Software	2
TD3 Electrical Power	
TD4 Spacecraft Environment & Effects	1
TD5 Space System Control	2
TD6 RF Payload	2
TD7 Electromagnetism Technologies & Techniques	
TD8 System Design & Verification	
TD9 Mission Operations & Ground Data Systems	
TD10 Flight Dynamics & GNSS	2
TD11 Space Debris	2
TD12 Ground Station System & Networks	
TD13 Automation, Telepresence & Robotics	3
TD14 Life and Physical Sciences	
TD15 Mechanisms	6
TD16 Optics	
TD17 Optoelectronics	1
TD18 Aerothermodynamics	
TD19 Propulsion	3
TD20 Structures & Pyrotechnics	1
TD21 Thermal	
TD22 Environmental Control Life Support	
TD23 EEE Components	
TD24 Materials & processes	3
TD25 Quality, Dependability & Safety	
TD 26 Others	

Table 12 Summary of the number of technologies developed by Polish entities under the NCRD and EU Horizon 2020 programs concerning generic technologies Source: own study

IV. Conclusions

Projects implemented by Polish entities under European Space Agency programmes - including in particular the programme implemented in the interim period (2012-2019) - Polish Industry Incentive Scheme, the EU Horizon 2020 programme and NCRD programmes related to the development of generic technologies - have made it possible to create a list of the most important technological domains in the Polish space sector.

Due to its importance, the number and value of completed or ongoing projects, the ESA Polish Industry Incentive Scheme had the greatest impact on POLSA's development of recommended areas.

A survey of 2020 among interested entities of the Polish space sector (both industry and R&D entities), who provided the Polish Space Agency with their data, and in-depth interviews combined with visits to selected entities constituted auxiliary and complementary material for creating a list of technology domains. Due to a not fully satisfactory number of completed questionnaires, i.e. 50 out of 98 sent to selected entities, the declared technology domains do not present a full picture of activities undertaken by Polish entities in this respect.

These are the following technological areas (random order):

Tech. domain no. (TD)	Name	Description
1.	TD 1: On-Board Data Subsystems	Systems for processing, storing and managing spacecraft and payload data, equipment and software necessary for data acquisition, management of the network layer, among others: • on-board and payload data processing systems; • machine learning and artificial intelligence for on-board data subsystems
2.	TD 2: Space System Software	Systems addressed to both space and ground-based stations, as well as techniques and technologies in software and information technology with respect to their application to -space missions. The domain includes: • advanced information technologies; • on-board and ground-based systems software; • ground-based data processing systems; • collection, archiving and processing of large scale data; • use of observation instrument data

Tech. domain no. (TD)	Name	Description
3.	TD 3: Spacecraft Electrical Power	Technologies related to electromagnetic system architecture, power generation and storage systems, power distribution (cabling) and air conditioning
4.	TD 6: RF Subsystems, Payloads and Technologies	The domain covers technologies related to satellite systems and networks, payloads, ground-based equipment, TT&C, navigation, Earth observation, operating in the microwave and millimetre wave frequency ranges, including • telecommunication and radio navigation systems and subsystems; • radio link technologies for telemetry, tracking, control and data transmission; • payload radio equipment; • components and subassemblies of on-board radio equipment
5.	TD 8: System Design & Verification	Technologies related to characterisation, design and testing of space systems; activities focus on reducing the time of development of new technology and production costs, risk control
6.	TD 9: Mission Operation & Ground Data Systems	Satellite operation, control and use of space and ground-based systems. The domain also describes the technology and support tool, focuses on Mission Control System (MCSs)
7.	TD 11: Space Debris	Includes technological and scientific information related to meteoroids and space debris, their impact on spacecraft, risk assessment and protection against such events, deorbiting space objects
8.	TD 15: Mechanisms	A technological domain for any device in which movement of one or more components is required, e.g. control mechanisms or actuators, among others. • release and retention mechanisms; • exploratory tool technologies; • electronic control technologies; • electromechanical microcircuits; • mechanism design methods and tools
9.	TD 19: Propulsion	Spacecraft propulsion processes and technologies, chemical and electrical propulsion for satellites of various sizes and launch systems and advanced non-classical methods

Tech. domain no. (TD)	Name	Description
10.	TD 20: Structures & Pyrotechnics	Technologies and methods related to design, analysis, production and testing of materials/ structures for space objects, degradable, high--stability and robust structures, hot structures as well as shields against meteorite and space debris impacts, pyrotechnics
11.	TD 24: Materials and Processes	The scope of the Materials and Processes domain includes, among other things, physicochemical properties of materials, materials mechanics, and manufacturing processes, materials modelling, non-destructive testing, materials and technologies ageing, their reuse and reliability, terrestrial and space effects on materials, additive manufacturing, and composite materials

Table 13 The most important technological domains indicated by national entities implementing projects within the framework of ESA's programmes and missions
Source: own study based on surveys and ESA information on PLIIS programme

e. Products or services provided by companies and scientific entities

Product classification of finished devices (components, subsystems or systems) is carried out by Polish entities based on the ESA document entitled **ESA Generic Product Tree.** The document was developed in 2011 (**Reference No: TEC-TP/0045**).

Products can be classified according to different criteria, e.g. on the basis of their scientific or research functionality, according to a criterion oriented to the development of a specific technology or according to the specific internal organisational structure of a particular industrial entity.

The classification of the product tree adopted by the European Space Agency has been made on the basis of the criterion of target application/use of products in the space sector. The purpose of the ESA product tree is to provide a generic, structured and complete classification of all products involved in space activities.

Products applicable to the space sector according to the nomenclature defined in the **ESA Generic Product Tree** document are assigned to four main segments:

- Segment I: Launching systems (Launchers);
- Segment II: Satellites & Probes;
- Segment III: Orbital Transportation and Re-Entry Systems;
- Segment IV: Ground Segment.

These, in turn, are divided into a number of systems, according to the following breakdown.

1. Segment name: Launching systems (I - Launchers)

This segment is divided into the following Systems:

- Avionics,
- Descent & Recovery,
- Materials,
- Mechanism,
- Parts,
- Propulsion,
- Software,
- Structures,
- Thermal Control.

2. Segment name: Satellites & Probes (II)
This segment is divided into the following Systems:

- AOCS & GNC,
- Electronics,
- Materials,
- Mechanisms,
- On-Board Software,
- On-Board data management,
- Optical Communication,
- Payloads/Instruments,
- Parts,
- Power,
- Propulsion,
- RF Microvawes,
- Structures,
- Thermal Control

3. Segment name: Space transportation and re-entry systems (III - Orbital transportation and re-entry systems)
This segment is divided into the following Systems:

- Descent & Recovery,
- GNC,
- Environment and Crew Life Support,
- Mechanisms,
- On Board Data Management,
- Power,
- Propulsion and Reboost,
- RF Comunication,
- Software,
- Structures,
- Thermal Control.

4. Segment name: Ground segment (IV)
This segment is divided into the following Systems:

- Mission Operations,
- Ground Station,
- Ground Segment Network,
- User Operations,
- Development and Construction of Space Segment.

A questionnaire survey among interested entities of the Polish space sector (both industry and R&D entities), who submitted their data to the Polish Space Agency, as well as in-depth interviews combined with visits to selected entities, allowed to create a list of products and services with the highest degree of advancement, which are in possession of national entities implementing projects within the framework of programmes and missions of the European Space Agency, as well as other institutions (EC, EUSPA or EUMETSAT).

It should be emphasised that, according to the list below, the dominant group of products owned or developed by Polish entities falls within Segment II (Satellites and Probes) and is prepared for the needs of satellites and space probes. This segment is dominated by products related to software and data processing, as well as IT systems for modelling and simulation:

- On-Board Software,
- On-Board data management,
- System Engineering Software.

Mechanisms and propulsion products (both for satellite systems and probes, as well as for launch and sub-orbital rocket systems), microwave and radio frequency products for satellite systems, probes and payloads, materials and structures are also of great importance. A large group includes products and services from Segment IV (Ground Segment), including applications for end users in the Downstream segment based on satellite data from observation or navigation satellites (Copernicus / Sentinel, Galileo).

A detailed list of the products of the Polish entities can be found in Annex No. 3 to this study.

f. Enterprise or research unit management models

Last year's POLSA/ESA survey involved several dozen (50) entities from the sector that submitted completed questionnaires. Among them were large enterprises, one micro-enterprise, SME type enterprises, eight scientific entities, including universities, scientific units - Łukasiewicz Research Network, Polish Academy of Sciences, research institutes. The result of the questionnaires confirms that the Polish space sector is clearly differentiated and divided into scientific area and industrial area. Polish institutions forming the system of higher education and science (several dozen centres in total) mostly have many years of experience in space activities and significant achievements in this area, especially in the construction of research instruments for scientific and educational missions and components for satellites, as well as satellite data processing.

Among industry entities, we can indicate the predominant share of limited liability companies; only three entities are joint stock companies.

Among the entities of the science sector, we can point to universities, research institutes, and institutes of the Łukasiewicz Research Network.

Most entities have an organisational structure with separate competent departments (R&D) and support departments - administrative, financial, legal, project management.

In the case of companies, the representation of the company by the management board - one or more persons, with the preference that each member of the management board may represent the company to the extent assigned to him/her. In a few cases a proxy has been indicated (lawyer - proxy).

The division of competences between CTO (Chief Technology Officer), COO (Chief Operating Officer) and CEO (Chief Executive Officer) is of key importance in the companies. When a company's

board consists of three people, the CEO is responsible for finance, the COO for sales and the CTO for technology.

In the case of having a branch, it was indicated that the branch was managed by a manager.

Micro-enterprises employ staff for competent departments, while they contract financial or HR services from external companies.

In the case of companies implementing projects for the Polish Armed Forces, there is a separate military department and space department. In the case of most large companies and SMEs, a sales and marketing/PR department is separated in the company's structure.

In companies originating from start-ups, there is no precise structure.

An example of a structure in a joint stock company is as follows:

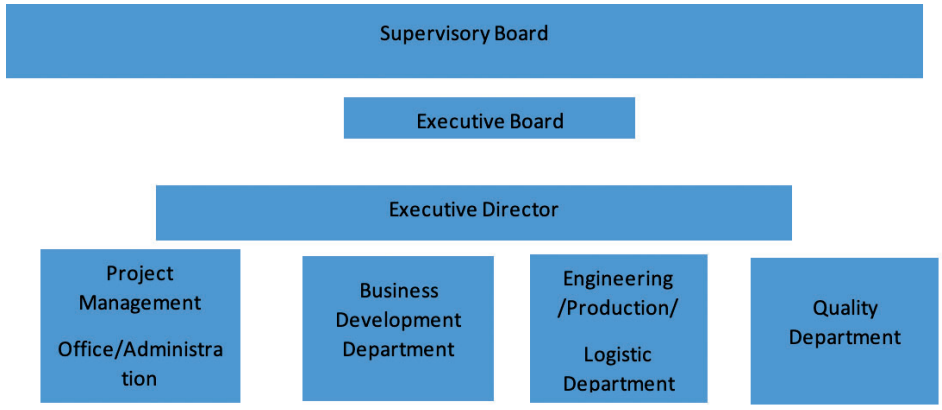

Figure 24 An example of a structure in a joint stock company
Source: own study

Example structure in a limited liability company:

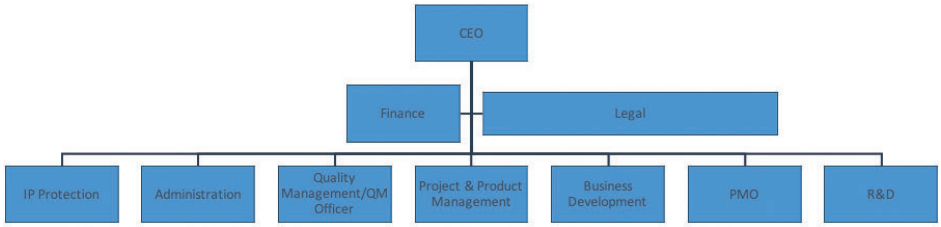

Figure 25 An example of a structure in a limited liability company
Source: own study

Project management in the business sector

Most companies have a separate project management structure in the form of R&D department and support department(s). In large companies, the project management structure includes a steering committee and supporting departments such as quality, purchasing, logistics, Lean management. In large companies and SMEs, there is usually a dedicated project management office/department. A project manager is identified for each project. Several companies indicated management based on Agile and waterfall methodologies, especially in IT projects. In several companies, space projects are also managed by a PMO (Project Management Officer) appointed by the director of the project management office. In small companies there is usually no formal division into offices or departments. Projects are managed by the R+D team involved in the project. In limited liability companies, the project support model is also used with the involvement of external consultants.

The reporting structure in a project is as follows: team member, team leader, project manager/project officer, area director/steering committee/company board member responsible for the business

area. Where a company has a departmental-based structure, each department consists of a departmental manager and staff.

With regard to projects, reporting is done in accordance with the project management methodology as appropriate for each project.

An example of a project management structure:

Figure 26 An example of a project management structure
Source: own study

In the case of research units and higher education institutions, the structure results from laws and statutes:
• Higher education institutions - in accordance with the Law on Higher Education of the 20th of July 2018 (Journal of Laws 2018 item 1668 consolidated text);

• Łukasiewicz Research Network - Act of the 21st of February 2019 on Łukasiewicz Research Network Journal of Laws of 2019 item 534;
• Scientific institutes - Act of the 30th of April 2010 on research institutes Journal of Laws of 2010 No. 96 item 618 as amended;
• Institutes of PAN - Act of the 30th of April 2010 on the Polish Academy of Sciences Journal of Laws of 2010 No. 96 item 619 as amended.

The management system varies in Łukasiewicz Research Network, institutes of PAN and research institutes.

Example of management system in a research institute: the institute is managed by the director personally or by persons subordinate to him - director(s) including the chief operating officer (deputy director), scientific secretary, heads of departments, chief accountant. Supporting functions are provided by the administrative and financial departments.

Project management in research institutes

Projects have an individual structure, which depends on the type of project. Space technology projects (the majority) have the key personnel necessary for the proper implementation of the projects.

Projects are carried out by research staff in thematically relevant departments, and administrative and financial support is provided by the administration department.

In their organisational structure, research institutes have units that conduct scientific research, development works and perform activities supporting research: scientific and research establishments, laboratories, departments - units performing functional and service activities, classified information protection division.

Research teams consist of a leader who is supported by administrative and financial departments. Typically, projects are assigned to units, although they may also be carried out by several departments or teams. The director of the institute appoints a project manager/ coordinator. The institute also has departments responsible for finance, marketing and promotion, as well as procurement.

Universities consist of faculties and research units where projects are implemented; support/servicing is provided by finance and administration departments. The implementation of projects is supported by several central offices. Each ESA project has an individual scheme in which the project leader (manager) is responsible for the implementation of the content-related tasks. The leader receives administrative, financial and procurement support. Additionally, the University of Warsaw has an International Research Projects Office and a Development Support Office.

3. Strengths and weaknesses of the Polish space sector

a. SWOT analysis of the Polish space sector in light of the Polish Space Strategy

For the purpose of developing the Polish Space Strategy, adopted by a resolution of the Council of Ministers on the 26th of January 2017, the strengths and weaknesses of the Polish space sector, as well as the opportunities and threats it faces, were collated. The attempt to characterise the entire branch of the economy is not an easy task. Conducting a detailed market analysis, however, allows to develop and implement actions aimed at supporting the sector's development and creating conditions for long-term investment. It also contributes to defining the chances of increasing competitiveness against foreign entities as well as to detecting and minimising threats that may be exacerbated if systemic measures are not implemented.

- Strengths

One of the main strengths of the Polish space sector, as indicated in the PSS, is the innovative potential of Polish companies. Small and medium-sized enterprises (SME) stand out in particular in this respect, which, according to the latest report of the European Space Agency ("Observatory of Country Capabilities - Analysis of Industrial participation of Polish industry to ESA's programmes 2015- 1Q2020), constitute 40% of all industrial entities participating in ESA[8] programmes. The space sector seems to be particularly attractive for entrepreneurial young people - students, PhD students or entrepreneurs, which increases its dynamism and flexibility. The high quality of education in technical sciences at Polish universities, especially in such subjects as mechanics, electronics, telecommunications or IT technologies, is not without significance, which translates at a later stage into transfers of technologies and competences from related fields (e.g. robotics or IT), more and more often adapted for use in space technologies and satellite techniques.

Polish space sector entities actively participate in scientific space projects offered by the European Union and the European Space Agency. The Polish Space Strategy (PSS) indicates a high degree of use of contributions to ESA 's optional programmes since 2012,

[8] *European Space Agency report 'Analysis of Industrial participation of Polish industry to ESA Programmes 2015-1Q2020', ESA | 01/09/2020 | Slide 5.*

when Poland became a member of ESA. This has contributed to the development of cooperation between Polish companies and scientific entities, thanks to which both parties fully benefit from the knowledge and competences available in Poland within the space sector. ESA representatives and foreign partners have positively assessed the quality and results of work carried out by Polish entities in the first projects for the European Space Agency, which only confirmed the significant potential characterising Polish entrepreneurs and scientific institutions.

- Weaknesses

Undoubtedly, a weakness of the Polish space sector is the relatively low level of state investment in this branch of the economy, which translates directly into slowly growing interest of private entities in both the upstream (technology supply) and downstream (technology use) segments. The lack of capital and the absence of dedicated domestic sources of space financing are a major obstacle to the development of the industry. PSS also points to the lack of sufficient national tools to support cooperation between companies and scientific entities.

An impediment to the commercial use of satellite techniques is the limited demand for such services from public administrations. Public administration is not aware of the usefulness of satellite data and is not properly trained to use it for the implementation of public tasks. Additionally, the Polish space sector still seems to be marginalised in social and media awareness. All these factors translate directly into a lack of companies with long-standing experience in launching objects into space (flight heritage).

- Opportunities

Space activity has great potential to become one of the most innovative branches of the Polish economy, especially taking into account the constantly developing new technologies and emerging technological niches in which Polish entities have a chance to specialise. Access to national and EU funds, the introduction of changes to the European space policy and the development of other branches of the Polish economy, such as the automotive, aviation and railway industries, as well as the defence industry, may help.

Another great opportunity for the Polish sector is the widespread use of satellite data by public administration bodies and their use in the

areas of security and defence. In turn, the tightening of international cooperation, both in the European and global perspective, will certainly affect the participation of Polish entities in new programmes and projects and their ability to perform export activities.

- Threats

As PSS points out, a major challenge for the Polish space sector is to gain experience in the area of space technology supply (upstream) due to, among others, the low share of Polish entities in the supply chain of major system integrators. In turn, the global and European downstream sector currently offers services resulting from long-term development works, with a much higher level of financing (often from public funds) in relation to domestic outlays.

In addition, a significant threat to the development of the space sector in the coming years is the lack of a national programme for the development of technological competence along the lines of the ESA and EU programmes and the lack of the necessary investment stability in the sector.

b. SWOT analysis of the Polish space sector in light of the survey and the European Space Agency report "Analysis of Industrial participation of Polish industry to ESA's programmes 2015-1Q2020"

In the aforementioned POLSA/ESA survey, the surveyed organisations were asked, among other things, to indicate the strengths and weaknesses of their space activities.

Subsequently, the European Space Agency developed the report "Observatory of Country Capabilities-Analysis of Industrial participation of Polish industry to ESA's programmes 2015-1Q2020", which compiled the most characteristic strengths and weaknesses of the Polish space industry. The conclusions are based on a survey of 18 Polish entities that gained the most contacts in ESA's programmes

between 2015 and Q1 2020 (over 70% of all 156 Polish entities executing contracts for the European Space Agency as a contractor or subcontractor[9]). To a large extent, they coincide with the SWOT analysis of the sector made in PSS as well as the self-analysis of entities surveyed by ESA[10] and POLSA as part of this year's sector survey for the adoption of the National Space Programme.

The questionnaire survey, as well as subsequent visits to the headquarters of selected entities and the abovementioned ESA report, made it possible to identify the most frequently distinguished strengths and weaknesses of the Polish space sector and the opportunities and threats which may affect its development.

It should be stressed that despite its small size in relation to the markets of long-term space players, the Polish space sector is not homogeneous. Even within the dozens of entities included in the sector, there are significant differences in the level of experience, infrastructure used or the way they are managed.

Strength

High competence of Polish entities in selected areas of space industry

The space sector is a relatively young branch of the Polish economy. Despite this, its entities have managed to gain high competence in many domains related to space activities. This is due to the active participation of entities in ESA and European Commission programmes, defence projects (NATO, European Defence Agency, GSA) or competitions held by the National Centre for Research and Development. The categories of products, technologies and services in which Polish enterprises as well as research and development units have so far developed the highest competence include:

- mechanisms;
- services, products and applications using Earth observation satellite data;
- propulsion;
- Electrical Ground Support Equipment (EGSE);
- on-board electronic systems;
- on-board software;
- SST applications;

[9] European Space Agency report "Analysis of Industrial participation of Polish industry to ESA Programmes 2015-1Q2020", ESA | 01/09/2020 | Slide 5.

[10] The information in this subsection is based on surveys from entities and the ESA report "Analysis of Industrial participation of Polish industry to ESA Programmes 2015-1Q2020".

- structures.

It is worth highlighting the significant successes of Polish entities in the field of space robotics, the construction of Mechanical Ground Support Equipment (MGSE), as well as the design of optical devices.

Strength

Technology transfer from fields related to the development of space technologies and satellite techniques, which increases the innovation of SMEs and entities carrying out R&D works

Extensive experience in IT, electronics, mechanics and telecommunications techniques directly translates into the ability of Polish entities to compete for contacts at the European or even global level. For example, thanks to a proven production system from related fields, it is much more efficiently implemented when improving another product. Such elements as robotic mechanisms, sensors, software or operational research simulators, as well as experience in participating in big data or cyber-security projects, prove extremely valuable in the field of development of indigenous space technologies and satellite techniques.

The Polish sector is also characterised by the ability to optimize costs and develop very quickly (especially looking at the last eight years, since 2012, when Poland became the 20th member of the European Space Agency). What is important, universities and scientific and research units constitute 20% of entities executing contracts with ESA for the development of specific products, which was positively assessed by the authors of the aforementioned report, and in a longer perspective and with a higher level of financing for R&D works, this share may increase.

Strength

Human capital - well-educated, young, motivated employees

Polish entities declare that their employees are well educated, being graduates or final-year technical, engineering or natural science faculties. Many of them assess their staff as ambitious, highly motivated, driven by curiosity and a desire for development. Their flexible and fresh approach to developing the necessary solutions bodes very well for the continued development of the Polish space sector's capabilities in the future. A huge role in this respect is played by domestic educational programmes and research clubs operating

at universities in the field of astronautics or robotics.

Strength

Drawing on the experience of international entities in the space sector

Some Polish companies are characterised by very close cooperation with major system integrators (LSI) and global leaders of the space industry. As a result, they receive support from experienced staff and their personnel improve their qualifications through participation in foreign training programmes. They have the opportunity to test their products by creating environments for their testing that are not yet available to local entities. International cooperation helps them to build the image of a reliable and professional entity, which will certainly influence the recognition of their brand in the entire space industry and the commercial success of the services and products they offer. On more than one occasion, the companies have also declared the introduction of English as the official language in all communication channels (including internal ones), which will make it easier for them to recruit experienced employees from other countries.

Weakness

Lack of sufficient experience in strict-space projects, lack of flight heritage

Strengths of the Polish space sector

- **High level of competence in certain areas of the space industry**
- **Technology transfers from related fields**
- **Human capital**
- **Drawing on the experience of international entities**

Based on this year's survey and visits to selected entities, it can be concluded that the Polish space sector is still at an early stage of development. Polish industrial, scientific and research entities lack experience in the upstream segment and in launching space objects (flight heritage), and lack a well-thought-out strategy on how such experience should be acquired.

The level of involvement in commercial space missions is relatively low. In the group of service providers and manufacturers in the supply chain on the space market, Polish entities are ranked as suppliers of raw materials/materials and suppliers of parts and subassemblies (although there are already companies which have managed to construct and successfully launch a satellite). Despite the aforementioned use of technologies from other areas of the market, some solutions cannot be copied 1:1 for use in strictly space-related projects. Some of the relevant space technologies have not yet been developed in Poland, which forces domestic entities to use the services and applications of foreign partners. While this builds business relations with international entities, it also makes the success of a given project or contract dependent on their participation. Many times companies that are part of large international capital groups have indicated that they are highly dependent on external entities, both in terms of technology and administration.

Weakness

Ineffective management and lack of specialised staff

A frequent problem pointed out by Polish entities was their low level of organisation at the administrative level and the lack of a business strategy or a development plan towards space technologies. Many companies also pointed to difficulties in managing projects and estimating their costs and risks. There is a lack of consistency in project roles and frequent replacement of staff. In practice, it even happens that the same group of people works on several projects simultaneously. The limitation of internal resources for sales processes, marketing activities or quality control in the product or application implementation phase was also mentioned several times. The management lacks market knowledge and experience in supervising space projects. Sometimes non-SMEs face low flexibility

of internal processes, which in case of unforeseen circumstances at the global level (example: COVID-19 pandemic) may hinder their proper and effective functioning.

Surveys have also shown that a significant obstacle to the development of the sector in Poland is the lack of experienced and specialised personnel capable of carrying out large space projects. It is not uncommon for companies in the sector to employ young, well-educated people, who lack the necessary experience and knowledge of the space sector. This affects the image of Polish entrepreneurs in the sector, who may be perceived as incompetent and their activity as uncompetitive on the market. What is more, the cost of training an employee can be high and the process lengthy - mainly due to many months of recruitment and subsequent adaptation to a new position. A very large number of entities have also reported the problem of frequent staff turnover.

Weakness

Lack of access to adequate laboratory and testing facilities

One of the most frequently mentioned weaknesses of the Polish space sector is a serious lack of access to infrastructure. Polish entities mainly lack testing facilities, clean rooms or properly equipped laboratories. The following graphic presents information on the specific infrastructural deficiencies of the Polish space sector. It was made on the basis of an analysis carried out by Industrial Development Agency JSC, complementing the sector survey:

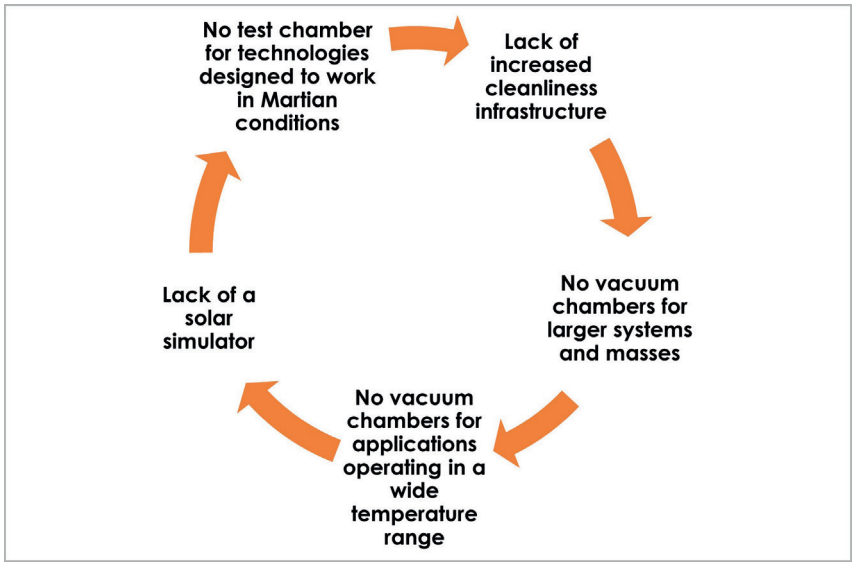

Figure 27 on the basis of an analysis entitled: "Laboratory and test infrastructure for the Polish space industry" with a description of the methodology for its development, for the needs of the National Space Program, carried out by Industrial Development Agency JSC

Weakness

Insufficient level of funding for the Polish space sector

The lack of sufficient financial resources for the development turned out to be another most frequently mentioned weakness of the Polish space industry. The end of the PLIIS support programme dedicated to Polish entities is now a major challenge in terms of raising funds. Most Polish entities do not have a stable and long-term source of funding for carrying out space activities, which are burdened with high risk and generate considerable costs. Production costs are constantly rising with relatively low income from sales of products and services or commercialisation of R&D work results.

Many entities have pointed out the dependence of implementing space projects or conducting R&D works on external sources of financing or co-financing by state institutions. In Poland, however, it is difficult to gain investors for activities which are simply unprofitable for a long time. Low employment rates, in turn, influence the lack of involvement of specialists in space activities, as well as high employee turnover on the market.

Another problem is connected with the difficulty in estimating the costs of contract implementation, especially when the so-called one-off costs occur, which are unexpected and difficult to calculate at the initial stage of work. Entities that belong to international capital groups or are part of a larger network of scientific and research institutions seem to be in a slightly better financial position.

Weaknesses of the Polish space sector

- **Lack of experience in implementing space projects**
- **Ineffective management and lack of specialised staff**
- **Lack of infrastructure**
- **Insufficient level of co-financing**

Opportunity

Poland's relatively high contributions to ESA's mandatory programmes and the EO optional programme

The relatively high amount that Poland contributes to ESA's mandatory programmes (amounting to €24 million in 2020[11]) was indicated many times in the results of the survey as a great opportunity for the Polish space sector. This represents an increase in the amount of €1 million compared to the 2018 contribution. This implies a correspondingly higher contribution[12] to ESA's Science programme, which is one of the mandatory programmes. Thanks to investing in mandatory programmes, Polish entities have a chance to continue (and perhaps in time even increase) their participation in missions such as Athena, Ariel or Comet Interceptor.

[11] European Space Agency report "Analysis of Industrial participation of Polish industry to ESA Programmes 2015-1Q2020", ESA | 01/09/2020 | Slide 4.

[12] Report "ESA programmes - opportunities for POLANO" IPL/TEC/EOP/SCI | 24/05/2018 | Slide 7.

With relatively low financial outlays for participation in ESA's optional programmes, it is worth noting that a significant part of the Polish contribution to optional programmes is allocated to Earth Observation - EOEP and MetOp-SG. The results of this year's survey of the Polish space industry emphasise that the ever-growing demand for the use of services and applications based on EO satellite data is a great opportunity for the Polish space sector. The databases of available satellite data are successively expanding, and they are received in ever higher resolution, even up to several times a day, thanks to which their commercial value is growing. Thus, the amount allocated for EO programmes may significantly influence further development of competences of Polish entities in the field of satellite data use and at the same time will influence the dissemination of their use by a wide group of users. The need to create a Polish EO constellation - the Satellite Earth Observation System, which will provide Poland with autonomous access to even more accurate satellite imagery, has also been pointed out many times.

Opportunity

National instrument for commissioned projects

Without continuous growth of innovation, the Polish space sector will not become competitive in relation to European and world markets, which are many times more experienced. The stimulation of the economy by the state administration may turn out to be the way to achieve this, but not by offering grants and subsidies for research and development activities, but by more frequent commissioning of projects aimed at creating a specific product or service. Polish entities have repeatedly stressed that market demand for the development of a specific technology or application is the most effective way to develop the industry and the commercial success of the results of their space activities. At the same time, from an economic point of view, national programs for commissioned projects will generate lower financial risk, as the final product will respond to the actual market needs and will be delivered to specific users. Thus, the programmes of commissioned projects can support the development and the degree of innovation in narrow specialisations and niches of the sector, such as cybersecurity, space debris mitigation, deorbitation or the so-called green propulsion.

Opportunity

Implementation of the National Space Programme

The need to develop and implement the National Space Programme has been signalled by many Polish entities. This programme, implementing the assumptions of the Polish Space Strategy, will set directions for development in the sector, introduce stable and long-term sources of financing and enable the development of areas and technologies important for the needs of security and public administration. It will also make it possible to systematise currently dispersed activities in the state's space sector and, at the same time, complement those activities in international organisations. The dissemination of the use of satellite data mentioned above in the Opportunities sub-section, as well as the programme of commissioned projects, thanks to implementation in the National Space Programme, will stimulate innovation in the sector and increase the competitiveness of Polish entities on the international arena.

Opportunities

Poland's relatively high contributions to ESA's mandatory programmes and EO optional programme

National instrument for commissioned projects

Implementation of the National Space Programme

Threat

Low contribution to most ESA's optional programmes

Optional programmes mainly serve to develop the individual scientific and technological potential of each ESA Member State. Thanks to them, Polish space sector entities can acquire or develop

technologies useful for the security and defence needs and create applications or products responding to the expectations of Polish users. The declared Polish contribution to optional programmes in 2016 amounted to €45m for the period 2016-2019. During the ESA Space19+ Ministerial Council in 2019, in turn, the amount of €39m spread over the period 2020-2022[13] was declared. In particular, the amount allocated to the PRODEX programme (development of scientific experiments for space missions), programmes in the area of technology development and navigation was reduced. Particularly worrying for the surveyed entities of the Polish space industry is the reduction of funds for the ESA GSTP optional programme in the field of the development of general technologies. As a consequence, this may significantly delay or even prevent them from conducting R&D work and developing key technologies as well as reduce their competitiveness vis-à-vis more developed and experienced foreign entities. Without achieving a higher TRL, Polish entrepreneurs will not be able to participate in tender procedures for more complex technological products and applications. Moreover, if the level of initial technological readiness is too low (below TRL 3 or 4), Polish entities will also not be competitive in open tenders conducted under ESA's mandatory programmes.

Threat

The prospect of reduced funding for ongoing projects

At the end of 2019, the PLIIS support programme for Polish companies came to an end, resulting in a significant drop in geographical returns for Polish entities in ESA's mandatory programmes in the first quarter of 2020.
This means that Polish companies are now winning fewer contracts compared to previous years (a ratio of 0.07 compared to 1.06 in Q4 2019)[14]. The lack of alternative lines of financing the development of the space sector in Poland may affect the lack of funds for new projects, but also the reduction of funds for those that are still in progress or even the withdrawal of financing for further works and the need to return the funds already received. Polish entities of the space sector have, on more than one occasion, raised concerns about the need to return funding due to failure to achieve the expected results of project implementation in the case of R&D works financed from public funds (e.g. NCRD programmes). The consequence of

[13] European Space Agency report 'Analysis of Industrial participation of Polish industry to ESA Programmes 2015-1Q2020', ESA | 01/09/2020 | Slide 4.

[14] European Space Agency report 'Analysis of Industrial participation of Polish industry to ESA Programmes 2015-1Q2020', ESA | 01/09/2020 | Slide 21

limiting funds for ongoing projects may turn out to be an outflow of Polish specialists abroad, as the increase in salaries in Poland is unlikely to equate to those on the European market within the next few years.

Threat

Perspective of global economic crisis

One of the most frequently cited threats to the Polish space sector was the prospect of an economic crisis caused by the COVID-19 outbreak. There were inevitably disruptions to supply chains, as well as stoppages in the production of parts and components, which also affected the higher costs of their subsequent transport. In the longer term, a reduction in the number of projects, a slowdown in the development of key technologies and the delay or cancellation of space missions can be expected as a result of the crisis. In addition, the amount of funding for space activities may be further reduced, which may consequently cause tension in relations between industry and scientific and research units, which are ultimately competing for the same funds.

Threats

- **Low contribution to ESA's optional programmes**
- **Reduction of funding for ongoing projects**
- **The global economic crisis**

4. Proposed directions of development / interventions resulting from the study

- Increasing the level of investment from the state budget in both the upstream and downstream segments, e.g. through projects in the NSP, NCRD and NSC.
- Increasing demand for the use of satellite data in public administration through legislative changes and continuous raising of awareness and competence of government officials in the use of satellite data.
- Supporting scientific and research units and universities in order to develop competences of scientific and research workers and education of students within studies dedicated to the space sector and public administration.
- Supporting space sector entities in the field of acquiring relevant experience in flight devices and achieving the appropriate "flight heritage".
- Increasing investments in laboratory and test infrastructure dedicated to the space environment.
- Increasing the amount of contribution to the European Space Agency's optional programmes dedicated to the development of satellite systems and subsystems.
- Supporting companies from the SME sector and conducting information activities in order to attract new entities, especially from technological domains of key importance in Poland, to the technology harmonisation process conducted by ESA since 2020, especially in the phase of the so-called Mapping of Industrial Competences of the European Space Sector. The most important conclusions and decisions from this phase (e.g. the needs of ESA and member states for future missions, technological requirements in specific domains, the need to raise the level of readiness of European technologies through ESA's programmes) are used in subsequent ESA activities (e.g. during work on work programmes and technology programme compendia: GSTP, Technology Development Element, ARTES, E3P/EXPERT

- Continuation, in cooperation with ESA, of specialised training courses and workshops for the space sector in Poland, including on preparing a competitive offer in response to a call for tender, ECSS space standards and quality management (PA/QA).
- POLSA's accession to the space standards organisation, ECSS, and participation in selected and more important working groups.
- Arrangements with ESA on the development of support mechanisms and actions to be taken by ESA and the Polish delegation to ESA to increase
- Proposed developments/interventions resulting from the study
- the participation of Polish entities, in particular from the SME sector, in ESA tender procedures for mandatory programmes, especially in the mandatory Scientific Programme, in which the current (as at 31.12.2020) geographical return for Poland is quite low and unsatisfactory (the return ratio is 0.30).
- It is advisable to carry out an evaluation of the ESA's project implemented from 2019 within the PLIIS/Roadmap programme on supporting the project management and quality implementation process in selected Polish Product Assurance/Quality Assurance entities and to take a possible decision and its continuation.

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Annexes
Annex No. 1

Detailed list of projects from NCRD programmes other than the fast track "Space Technologies": Annex No. 1

Name of the project	Entity	Area of application	Project status
Lightweight nanocrystalline aluminium--based material for aerospace applications (modelling and technology verification) LIGHTMAT4SPA- CE	Łódz University of Technology	12.2 R&D activities related to engineering and technical sciences, funded by GUF/r/n	completed
Water in soil - satellite monitoring in improving water retention using biochar	Institute of Agrophysics, Polish Academy of Sciences	2 Environment	current
New observation tools for remote monitoring of the marine environment and their application in studies of groundwater discharge (SGD) and seabed	Maritime University of Gdynia, Maritime Institute	4 Transport, telecommunications and other infrastructure	current
New observation tools for remote monitoring of the marine environment and their application in studies of groundwater discharge (SGD) and seabed	NOA Sp. z o.o.	4 Transport, telekomunikacja i pozostała infrastruktura	current
An innovative near real-time landslide monitoring service based on satellite radar data	SATIM Satellite Monitoring Sp. z o.o	1 Exploration and exploitation of land	current
An innovative near real-time landslide monitoring service based on satellite radar data	ICEYE Polska Sp. z o.o.	2 Environment	current
Image stream transmission using satellite communications critical to unmanned aerial vehicle missions	Robot Aviation Sp. z o.o.	4 Transport, telecommunications and other infrastructure	current
Analysis of new therapeutic strategies in a preclinical model of HGPS-type progeria	University of Wrocław	12.3 R&D activities related to medical sciences, funded by GUF/r/n	current

Name of the project	Entity	Area of application	Project status
MARS - commercially available lever technology with integrated deflection detectors for near-interaction microscopy	IGHT spółka cywilna Ignacy Moscicki Grzegorz Kaszynski	13.2 R&D activities related to engineering and technical sciences funded from sources other than GUF/r/n	current
Satellite-based crop identification and monitoring for agricultural statistics	Central Statistical Office	0	current
Development and validation of a satellite manipulator control system	Space Research Centre of the Polish Academy of Sciences	3 Exploration and exploitation of space	current
Navigation microcontroller for centimetric satellite navigation with hardware-based position authentication for autonomous devices	ChipCraft Sp. z o.o.	7 Health protection	current
Satellite-based laser collision hazard detection system	Creotech Instruments SA	3 Exploration and exploitation of space	current
Development and validation of a laboratory model of a space robot incorporating a resistojet motor system	Space Research Centre of the Polish Academy of Sciences	13.2 R&D activities related to engineering and technical sciences funded from sources other than GUF/r/n	completed
Planetary penetrator for geological research for a space mission	Space Research Centre of the Polish Academy of Sciences	13.2 R&D activities related to engineering and technical sciences funded from sources other than GUF/r/n	current
Multi-criteria routing algorithms for a fleet management support system	Gdańsk University of Technology	13.2 R&D activities related to engineering and technical sciences funded from sources other than GUF/r/n	current

Name of the project	Entity	Area of application	Project status
Application of the AIA (Adaptive Impact Absorption) concept in aerospace engineering AIA-Aero	Institute of Fundamental Technological Research of the Polish Academy of Sciences	6 Production and industrial technology	current
Development of technology of high--pressure gas hardening of satellite gears of epicyclic FDGS aircraft engine, made of Pyrowear 53 steel and working under long-lasting and cyclically changeable operating loads	Ignacy Łukasiewicz Rzeszów University of Technology	0	current
Development of advanced methodologies for multisystem (BDS, Galileo, GPS) real-time ionospheric services	University of Warmia and Mazury in Olsztyn	13.2 R&D activities related to engineering and technical sciences funded from sources other than GUF/r/n	current
RENESANS Project, a satellite platform in the new Hyper- Cube standard.	Creotech Instruments SA	9. Exploration and exploitation of space	current
Development and field verification of an integrated SAR radar management module dedicated to surveillance microsatellites	Scanway Sp. z o.o.	7. Industrial production and technology	current
ScanSAT - a platform for satellite and aerial observations for acquiring geoinformation in real time with high precision and in a very wide electromagnetic band	Space Research Centre of the Polish Academy of Sciences	9. Exploration and exploitation of space	current
Cryptographic satellite and inertial navigation receiver for unmanned aerial vehicles	Hertz Systems Ltd. Sp. z o.o.	7. Industrial production and technology	current
Development of technologies for large area autonomous gas detectors for ionising radiation, including cosmic radiation	Technology Transfer Agency Techtra Sp. z o.o.	12. Other civil research	current

Name of the project	Entity	Area of application	Project status
Innovative hyperspectral system for Earth observation (HyperCam) with increased -spectral resolution to enable automatic processing and selection of in-orbit satellite data based on new algorithms for satellite image segmentation and classification using deep convolutional networks	KP Labs Sp. z o.o.	7. Industrial production and technology	current
R&D work on the development of an innovative photographic lens for the first Polish commercial Earth observation nanosatellite	Renata Adamczyk Q Media	7. Industrial production and technology	current
Development of a multifunctional enclosure for aerospace electronics with special focus on "power electronics" and power sources	Blue Dot Solutions Sp. z o.o.	7. Industrial production and technology	current
SIR - steerable and recoverable suborbital rocket with SF1000 hybrid engine based on green propellants	Spaceforest Sp. z o.o.	9. Exploration and exploitation of space	current
Development of a revolutionary Earth imaging service using the REC satellite constellation	Satrevolution S.A	9. Exploration and exploitation of space	current
Development of new biopolymer biodegradable packaging for the cosmetics industry	Novo-Pak Sp. z o.o.	7. Industrial production and technology	current
An intelligent on-board computer for nano- and microsatellites with improved reliability and increased computing power, allowing on-orbit satellite self-diagnosis using machine learning algorithms for anomaly detection in telemetry data	KP Labs Sp. z o.o.	7. Industrial production and technology	current
ASTRO-MODULES - set of functional blocks for small and medium satellites	Astronika Sp. z o.o.	9. Exploration and exploitation of space	current
Self-tuning electronic controller of a satellite quantum entanglement generator	Syderal Polska Sp. z o.o.	7. Industrial production and technology	current
Development of a satellite service to support precision agronomic measures	Wasat Sp. z o.o.	9. Exploration and exploitation of space	current

Name of the project	Entity	Area of application	Project status
System for monitoring signals of satellite navigation systems in the environment of critical infrastructure	Blue Dot Solutions Sp. z o.o.	12. Other civil research	current
Development of a pioneering multifunctional 3D FFF printing robot with an integrated 7-degree-of-freedom robotic arm and innovative proprietary filaments to achieve endurance in printed models for use in the armaments, aerospace and military industries	Omni3d Sp. z o.o.	7. Industrial production and technology	current
Modular observation-inspection system based on a multirotor flying platform powered from a ground station	Moose Sp. z o.o.	7. Industrial production and technology	current
ReMY - Remote Mars Yard	ABM Space Sp. z o.o.	12. Other civil research	current
Mars simulator as a teaching and development tool	One More Level S.A.	11. Non-directed research	current
Bio-nanosatellite using miniaturised lab-on-a-chip instruments and methodology for conducting biomedical research using it in microgravity conditions	Satrevolution S.A.	4. Health protection and health improvement	current
Sustainable management of agricultural crop productivity using satellite imagery, based on personalised GIS services made available through a dedicated portal	University of Life Sciences in Poznań	8. Agriculture	current
Automatic system for monitoring the impact of high-energy parasitic ground shaking using GNSS/PSIn- SAR satellite -observations and seismic measurements	KGHM Cuprum Sp. z o.o. - Research and Development Centre	1. Exploration and exploitation of the -Earth	current
Miniature, dual-frequency, single-chip integrated system for precise GPS/GALILEO satellite navigation integrated with an application processor dedicated to low-power IoT devices	Warsaw University of Technology	7. Industrial production and technology	current

Name of the project	Entity	Area of application	Project status
EXOMHYDR - magmatic plumbing systems and tectonic control of hydro-thermal activity on Mars revealed by ExoMars/TGO: constraints for life and resources	Research Centre Space Rese-arch Centre of the Polish Academy of Sciences	no data available	current
Adaptation of the second degree course, Space and Satellite Technologies, to the needs of the labour market	Gdańsk University of Technology	no data available	current
Stop - the 4th planet from the Sun!	Pomeranian University in Słupsk	no data available	current
PLANET OF CREATIVE ENGINEERING 4.0	Tadeusz Kościusz-ko Cracow University of Technology	no data available	current

Annex No. 2

Space-related projects in H2020

Acronym	Project title	Project type	Start date	Completion date	Project budget	Role in the project	Net financing of the Polish entity
MyOcean FO	Pre-Operational Marine Service Continuity in Transition towards Copernicus	CSA	01.10.2014	31.05.2015	6 000 000,04 €	PARTICIPANT	5 689,40 €
HYPROGEO	Hybrid Propulsion Module for transfer to GEO orbit	RIA	01.02.2015	31.01.2018	2 993 888,00 €	PARTICIPANT	113 625,00 €
C3PO	advanced Concept for laser uplink/ downlink Communi-Cation with sPace Objects	RIA	01.06.2015	30.09.2017	1 133 017,50 €	PARTICIPANT	55 003,00 €
PERASPERA	PERASPERA (AD ASTRA) Plan European Roadmap and Activities for SPace Exploitation of Robotics and Autonomy	CSA	01.10.2014	30.09.2019	3 558 166,40 €	PARTICIPANT	0,00 €
COSMOS2020	Cooperation Of Space NCPs as a Means to Optimise Services under Horizon 2020	CSA	01.01.2015	31.05.2019	2 221 150,16 €	PARTICIPANT	200 972,46 €
Odysseus II	Youth for Space Challenge - ODYSSEUS II	CSA	01.01.2015	31.12.2017	2 076 788,13 €	PARTICIPANT	135 300,00 €
DEMETRA	Demonstrator of EGNSS Services based on Time Reference Architecture	IA	01.01.2015	31.12.2016	4 366 058,75 €	PARTICIPANT	324 887,50 €
GALENA	Galileo-based solutions for urban freight transport	IA	01.01.2015	31.03.2017	1 267 238,75 €	PARTICIPANT	128 093,75 €

E-KnoT	E-GNSS Knowledge Triangle	CSA	01.01.2015	31.05.2018	1 674 323,75 €	PARTICIPANT	137 973,75 €
POSITION	POlish Support to Innovation and Technology IncubatiON	CSA	01.01.2015	31.12.2016	314 125,00 €	COORDINATOR	187 625,00 €
CaBilAvi	Capacity building for aviation stakeholders, inside and outside the EU	CSA	01.01.2015	30.09.2017	1 857 175,75 €	PARTICIPANT	30 877,50 €
ADR1EN	First European System for Active Debris Removal with Nets	SME-2	01.04.2015	30.09.2017	1 730 000,00 €	PARTICIPANT PARTICIPANT	323 750,00 € 293 125,00 €
EcoSpacePropulsion	Piloting and upscaling the unique on site and mobile production plants for highly concentrated Hydrogen peroxide (HTP) production for space industry applications	SME-1	01.03.2015	31.05.2015	71 429,00 €	COORDINATOR	50 000,00 €
MOBNET	MOBile NETwork for people's location in natural and man-made disasters	IA	01.01.2016	28.02.2018	1 242 533,75 €	PARTICIPANT	107 625,00 €
SBNAF	Small Bodies: Near and Far	RIA	01.04.2016	31.03.2019	1 545 000,00 €	PARTICIPANT	287 500,00 €
ONION	Operational Network of Individual Observation Nodes	RIA	01.01.2016	31.12.2017	2 598 820,00 €	PARTICIPANT	200 000,00 €
SMS	SANDWICH MATERIAL AND STRUCTURE	RIA	01.01.2016	30.04.2018	1 187 742,50 €	PARTICIPANT	156 250,00 €

Acronym	Project title	Project type	Start date	Completion date	Project budget	Role in the project	Net financing of the Polish entity
INUNDO	INUNDO - The European Flood Database	SME-1	01.06.2016	30.11.2016	71 429,00 €	PARTICI-PANT	0,00 €
SENSAGRI	Sentinels Synergy for Agri-culture	RIA	01.11.2016	31.10.2019	1 854 757,50 €	PARTICI-PANT	135 750,00 €
I3DS	Integrated 3D Sensors suite	RIA	01.11.2016	31.01.2019	3 393 663,75 €	PARTICI-PANT PARTICI-PANT	198 700,00 € 313 718,75 €
INTERSTEL-LAR	Building the next generation high-speed data converters to strengthen European ex-cellence and competitiveness on space applications and beyond	RIA	01.12.2016	30.09.2021	7 309 500,50 €	PARTICI-PANT	18 750,00 €
SARA	Search And Rescue Aid and Surveillance using High EGNSS Accuracy	IA	01.02.2018	31.01.2020	1 942 327,50 €	PARTICI-PANT	129 050,00 €
CANDELA	Copernicus Access Platform Intermediate Layers Small Scale Demonstrator	RIA	01.05.2018	31.10.2020	1 998 011,25 €	PARTICI-PANT PARTICI-PANT	121 156,25 € 100 250,00 €
HATCH	SME-led Space Portal for Europe	CSA	01.11.2017	30.06.2019	512 891,25 €	COORDINA-TOR	99 095,00 €
FLAMINGO	Fulfilling enhanced Location Accuracy in the Mass-mar-ket through Initial GalileO services	IA	01.11.2017	30.04.2020	2 770 360,00 €	PARTICI-PANT	171 281,25 €

Aerobits	Aerobits - world smallest ADS-B receivers to safely integrate drones into European airspace	SME-1	01.12.2017	31.05.2018	71 429,00 €	COORDINATOR	50 000,00 €
PRO-ACT	Planetary RObots Deployed for Assembly and Construction Tasks	RIA	01.02.2019	31.01.2021	3 100 000,00 €	PARTICIPANT	400 000,00 €
EROSS	European Robotic Orbital Support Services	RIA	01.02.2019	31.01.2021	3 937 223,75 €	PARTICIPANT	311 250,00 €
IMPRESSIVE	Integrated Marine Pollution Risk assessment and Emergency management Support Service In ports and coastal enVironmEnts	IA	01.12.2018	31.05.2021	2 210 304,29 €	PARTICIPANT	114 275,00 €
HEATPACK	new generation of High thErmAl efficiency componenTs PACKages for space	RIA	01.01.2019	31.12.2021	2 941 298,75 €	PARTICIPANT	269 630,00 €
COSMO-S2020plus	Continuation of the Cooperation of Space NCPs as a Means to Optimise Services under Horizon 2020	CSA	01.06.2019	30.06.2020	600 000,00 €	PARTICIPANT	128 738,75 €
HUUVER	Hybrid UAV-UGV for Efficient Relocation of Vessels	IA	01.12.2019	31.05.2021	1 622 987,50 €	PARTICIPANT COORDINATOR	261 187,50 € 251 300,00 €
GEONAV IoT	Galileo dual frequency, 5G, IoT devices and services for Drones, Assets Management and Elite sport	IA	01.12.2019	31.05.2021	1 880 882,50 €	PARTICIPANT PARTICIPANT	181 300,00 € 176 575,00 €

Acronym	Project title	Project type	Start date	Completion date	Project budget	Role in the project	Net financing of the Polish entity
ENTRUSTED	European Networking for satellite Telecommunication Roadmap for the governmental Users requiring Secure, inTeroperable, InnovativE and standardiseD services	CSA			4 173 543,75 €	PARTICIPANT PARTICIPANT	0,00 € 862 962,50 €
Go2Space--HUBs	Generating new sOlutions 2 and from Space through effective local start-up HUBs	CSA	01.12.2019	30.11.2021	1 106 626,25 €	PARTICIPANT	203 012,50 €
SnapEarth	Fostering Earth Observation market uptake thanks to natural and holistic access to added value data generated through cutting-edge Artificial Intelligence technologies	IA	01.12.2019	31.05.2022	2 688 173,21 €	PARTICIPANT	205 887,50 €
NEOROCKS	The NEO Rapid Observation, Characterization and Key Simulations	RIA	01.01.2020	30.06.2022	2 114 725,00 €	PARTICIPANT	83 190,00 €
PERASPERA-X	Plan the European Roadmap and its Activities for SPace Exploitation of Robotics and Autonomy - eXtended	CSA	01.10.2019	31.03.2023	3 121 600,00 €	PARTICIPANT	14 955,00 €

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Annex No. 3

Detailed list of products of Polish entities

No.	Segment	Product/service name	Name of the entity
1	Satellites & Probes: Structures	Shock-mitigating frame support for pyro valve	Adaptronica
2	Satellites & Probes: Mechanism/ Microvibration damping (active and passive)	Active vibration cancellation system for cryocooler. Passive vibration damping system for control momentum gyroscope	Adaptronica
3	Ground Segment: EGSE	Ground Support Equipment	Astri Polska
4	Satellites & Probes: Space Applications Software (SAS)	Space Applications and Services, SW for downstream	Astri Polska
5	Satellites & Probes: Mechanisms/Hold Down & Release Mechanisms	incl. HDRM for EUROSTAR 3000 satellite platform, HDRMs for Prospect package for Luna-27	Astronika
6	Satellites & Probes: Mechanisms/Tubular Boom technologies	TB-based manipulators, deployers and antennas for i.a. JUICE RPWI, HERA Juventas and RadCube CubeSats, deployment dampers	Astronika
7	Satellites & Probes: Mechanisms/Penetartors	Drive mechanism for HP3, drill for Prospect	Astronika
8	Launchers: Structures	Multiphysics simulations , Validation, prototyping	CIM-mes Projekt
9	Launchers, Satellites & Probes/On Board Software	Thermal and Structure Engineering Software	CIM-mes Projekt
10	Launchers: Software	System Modeling and Simulation – on-board equipment	CIM-mes Projekt
11	Ground Segment/Services: EO Data storage, processing and dissemination	User operations, Storage(EO data in cloud related object), Cloud processing and dissemination of high volume (Copernicus DIAS Model)	CloudFerro
12	Ground Segment/Services: EO data Platform as a Service services	PaaS services related to use of EO data in the cloud environment	CloudFerro

No.	Segment	Product/service name	Name of the entity
13	Ground Segment/Services: Private and Hybrid Cloud Services	Cloud and storage services in private and hybrid mode for space related customers (e.g. ESA) but in no space related subjects – e.g. internal IT	CloudFerro
14	Ground Segment/Services: EO Very High Resolution data delivery	Storage, Paas (indexing, ingestion, discovery) and dissemination services for VHR data from various satellite providers	CloudFerro
15	Satellites & Probes: On-Board Software, On-Board data management, Optical Communication, RF Microwaves, Power,	Two Onboard Computers, Space and Ground Software, Power Architecture, PCDU, Telecommunication subsystem for the HYPERSAT microsatellite platform (30-60kg satellite)	Creotech Instruments
16	Ground Segment/Services: EO Data storage, processing and dissemination	User operations, Storage(EO data in cloud related object), Cloud processing and dissemination of high volume (Copernicus DIAS Model)	Creotech Instruments
17	Ground Segment/Services:	Integrated Applications: EUROPORT, ISSWIND, FLIPA GNSS signal processing: WAKATI	GMV
18	Satellites & Probes: RF Microvawe	Pre-development: GNSSW: GNSS SW-SW (GNSSW) Receiver for Space Multiple Applications, GNSS SW Receiver for Space applications – Multicore Application SW on Next Generation Multicore Processor, SW DEFINED RADIO GNSSW RECEIVER FOR MICRO--LAUNCHERS AND MICRO-SATELLITES	GMV
19	Satellites & Probes: On Board Software, On Board Data Management	On-board SW: on-board SW for OPS-SAT, Sentinel5 ICS Application SW, Engineering support: MetOp-SG GPP&ISD, BIBLOS, a Data Processing Centre – Task Manager (DPCTM) product, Orbit and Attitude Processor and Aeolus/ EarthCARE Browse Processors Developments, SWARM-DISC	GMV
20	Ground Segment: GNSS receivers dedicated for land platforms (military)	Downstream - Land applications – military GNSS receivers integrated with SAASM crypto module	Hertz Systems

No.	Segment	Product/service name	Name of the entity
21	Ground Segment: Vehicles monitoring system based on GNSS	Downstream – Land applications – GNSS based vehicle monitoring system	Hertz Systems
22	Ground Segment: Galileo/GPS system for vehicles/people/ assets monitoring	Downstream – land applications – Dual satellite navigation system for vehicles and people monitoring	Hertz Systems
23	Ground Segment: Galileo PRS receivers for governmental users	Downstream – Galileo PRS receivers – low end versions, dedicated for governmental authorities	Hertz Systems
24	Satellites & Probes: Payloads/Instruments	I1 RF and microwave Instruments/ I all.1 Instruments – BB	ICEYE Poland
25	Satellites & Probes: On Board Software	E1 Operating Systems/ E2 Libraries SW / E3 Re-usable / customisable SW applications	ICEYE Poland
26	Satellites & Probes: Power	J7 Storage: Batteries/ J8 Power Monitoring and Control/ J9 Power Eng.	ICEYE Poland
27	Satellites & Probes: RF/ Microvawe, Communication (Platform and Payloads)	L1 Antennas/ L2 Transmitters/ L3 Receivers/L4 Repeaters and Transceivers/ L5 RF Comm. Eng.	ICEYE Poland
28	Satellites & Probes: Structures	N1 Satellite Bus/ N2 Primary Structures/ N3 Secondary Structures/ N4 Folded structures/ N8 Struct. Eng.	ICEYE Poland
29	Ground Segment: Mission Operations	A1 Control Centre general equipment/ A2 Mission Control/ A3 Operations Execution	ICEYE Poland
30	Ground Segment/Ground Station	B5 Ground Station Monitoring & Control/ C Ground Segment Network/ D User Operations	ICEYE Poland
31	Satellites & Probes: Optical Communication	CFRP-integrated optical fiber sensor for structural monitoring (strain, temperature, pressure)	InPhoTech
32	Satellites & Probes: Optical Communication	Multi-core radiation-hardened erbium doped optical fiber and optical fiber components for onboard space applications	InPhoTech
33	Ground Segment Support Software	Solutions supporting engineers in AIT activities	ITTI

No.	Segment	Product/service name	Name of the entity
34	Launchers/Satellites & Probes: Propulsion/Chemical Propulsion	Production of 98% Hydrogen Peroxide	Jakusz SpaceTech
35	Launchers: Propulsion	Small suborbital rockets and propulsion systems	Łukasiewicz Research Network, - Institute of Aviation
36	Ground Segment/Downstream Services	Environmental monitoring and protection, risk assessment. Applications of remote sensing, geo-information, geophysics. Remote Sensing method for crops assessment	Łukasiewicz Research Network, - Institute of Aviation
37	Launchers/Satellites & Probes: Propulsion/ Green Spacecraft Propulsion	SmallSat green monopropellant propulsion system. Green Bipropellant Engine/Thruster.	Łukasiewicz Research Network, - Institute of Aviation
38	Satellites & Probes/On-board SW/Re-usable/ customizable SW applications	On Board Computer (OBCS). Oryx OBCS is a modular flight software tool developed for the mission control of small satellites. It manages all satellite tasks – processing telecommands, monitoring the power budget, executing pre-defined schedules, managing emergencies and handling data from all the sensors on board	KP Labs
39	Satellites & Probes/ On-board Data Management/ On-board Data Management	Leopard - a CubeSat standard compliant FPGA-based Data Processing Unit enabling mission designers to apply Artificial Intelligence solutions in space. It was designed to support the capturing, managing and processing of data in orbit using Deep Learning Networks	KP Labs
40	Satellites & Probes/ Payloads / Instruments/ Optical Instruments	A CubeSat standard compliant optical instrument, designed for hyperspectral camera using up to 150 spectral bands in the range of 470 nm – 900 nm. Instrument can be adapted to other cameras	KP Labs

No.	Segment	Product/service name	Name of the entity
41	Satellites & Probes: On Board Software	Flight SW - R&T activities related to Flight Software	N7 Space
42	Satellites & Probes/Mechanism	Grippers	PIAP Space
43	Ground Segment: MGSE	Adaptors like GSE (GHA, THA, VHA, acoustic mounts, clamp bands, other mechanical IF for S/C testing...), Special GSE (S/C and payloads dummies, micro vibration devices, gravity compensation devices...), Integration stands (VIS, MPT, PIS, SAS, rotating stands...)	PIAP Space
44	Ground Segment: Space Software	Software for objects recognition on SAR images. Ground motion products	SATIM Monitoring Przestrzenny
45	Satellites & Probes: Optical Communications	Optical comm with BB – currently internal R&D in this area	ScanWay
46	Satellites & Probes: Parts	Optical parts (designing) – being R&D subcontractor for designing and externally manufacturing optical parts	ScanWay
47	Satellites & Probes: Payloads and Instruments	Infrared and optical instruments – imaging payloads for smallsats	ScanWay
48	Satellites & Probes: System Engineering Software	Mission design – only Earth Observation missions	ScanWay
49	Satellites & Probes: Structures	Optical benches, structures for optics	ScanWay
50	Ground Segment	Optical GSE	ScanWay
51	Orbital transportation and Re entry systems/ Mechanisms	Visual video targeting and vision systems for docking and in-orbit maneuvering – Scanway sees it as a future perspective market	ScanWay
52	Ground Segment : Development and Construction of Space Segment	MGSE, (Containers, stands, handling and lifting equipment, mechanical integration tools, adapters)	SENER
53	Satellites & Probes / Mechanism	Deployment Mechanism, Release mechanism	SENER

No.	Segment	Product/service name	Name of the entity
54	Launchers: Mechanisms	Hold Down and Release Mechanism, Not-Explosive Actuators	SENER
55	Satellites & Probes / RF-Microwave Communication (Platform and Payloads)	Antenna Pointing Mechanism	SENER
56	Orbital Transportation & Re-entry Systems / Mechanisms	Docking Mechanism	SENER
57	Satellites & Probes/Materials	Composite materials – equipped structural sandwich substrates (CFRP or Al skin + Al honeycomb core)	ŚCNTPL
58	Ground Segment: Mission Operations, Ground Station, Ground Segment Network, User Operations	Software, hardware, services	Sybilla Technologies
59	Launchers: Mechanisms, Propulsion, Structurs	Simulations and Analysis: Radiation, Mechanical, Structural	Space Forest
60	Ground Segment	Autonomous tracking and data exchange system RASEL	Space Forest
61	Launchers	Launch vehicles	Space Forest
62	Satellites & Probes: RF Microvawe	RF filters, combiners, antennas	WiRan


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