SCIENCE AND TECHNOLOGY FORESIGHT PROJECT KK.01.1.1.03.0001

ANALYTICAL REPORT OF THE CONDUCTED SCIENTIFIC AND TECHNOLOGICAL MAPPING

SPACE TECHNOLOGIES

Inovacije i razvoj d. o. o., Zagreb
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1. Introduction

The Ministry of Science and Education (hereinafter: the Ministry), in cooperation with the University Computing Centre of the University of Zagreb (Srce), is implementing a strategic project titled 'Science and Technology Foresight', co-financed by the European Regional Development Fund. The overall objective of the project is to create a coherent and comprehensive system for determining the priorities of research, development and innovation policies in the Croatian scientific space. This will be achieved by implementing three main project elements: 1) establishing a legal framework, 2) creating the Croatian Research Information System, CroRIS, and 3) implementing scientific and technological mapping and foresight activities. The project will facilitate the cooperation among the representatives of the relevant ministry, the scientific community, the economic sector and civil society for the purpose of creating a comprehensive system for research, development and innovation. More about the project can be found at https://mzo.gov.hr/istaknute-teme/eu-fondovi/operativni-program-konkurentnost-i-kohezija-2014-2020/strateski-projekt-znanstveno-i-tehnologijsko-predvidjanje/851.

As part of the third project element, titled Implementation of Scientific and Technological Mapping and Foresight, the second phase of the mapping activities has been carried out for two new areas: Artificial Intelligence and Space Technologies. The objective of carrying out this mapping activity is to establish a comprehensive database of research competence, innovation capacity of scientific institutions and private sector entities operating in the new areas of artificial intelligence and space technologies. An in-depth analysis of the data collected from these two areas will indicate the strengths of the research sector and the overlap areas for potential identified in the said areas, thus helping to determine the priorities for the development of science and innovation in the Republic of Croatia and to align with the relevant policies at the EU level. This will enable the identification of productivity, competence, expertise, strengths and weaknesses of the Croatian science and technology system with a focus on human resources, technology transfer, synergies, strengthening participation in EU framework programmes, internationalisation, inclusion in the European Research Area and innovation as well as financial operations in the selected thematic areas. An insight into the areas of concentration of Croatian scientific and innovation excellence will enable the review of strategic documents in the field of research, development and innovation (RDI). This document presents the mapping of the Space Technologies area.

The methodological framework established by previously conducted mapping in the Energy and Sustainable Environment area within the same project is the starting point for the implementation of mapping and the establishment of methodologies for new areas. This document presents an analysis of the new Space Technologies area and the mapping of stakeholders under it using a professional review of their activities.

The process of collecting and processing data for this study was harmonised at all times with the relevant regulations related to personal data protection (the General Data Protection Regulation — Regulation (EU) 2016/679 and the Act on the Implementation of the General Data Protection Regulation (NN 42/18)).

1.1. Context of Mapping

Over the last ten years, space technology has seen significant development in various fields. Some of the major events in the field of space technology over the last ten years are the programme for re-establishing a human presence on the Moon (NASA plans to once again send humans to the Moon through the Artemis programme), the further development of space capsules intended for humans (in the last ten years, space agencies and private companies have developed new capsules for human transport that are designed for the safer transport of astronauts into space), SpaceX launching Crew Dragon in 2020 and subsequently performing several successful missions, the installation of a rover on Mars (NASA sent the Perseverance rover to Mars in 2021, equipped with the latest technology for studying the planet).

The European Space Agency (ESA) has also been very active in the past decade. Some of the activities carried out previously or currently by the ESA are: (i) Galileo: the ESA has continued to develop its Galileo navigation satellite system. The first-generation Galileo system (G1) is fully operational and has more than 3 billion users worldwide. The first phase of the system's high-accuracy service started in July 2022 with very good positioning accuracy performance. The ESA continues to develop the second-generation Galileo system (G2); the review of the preliminary design of the system is planned to be completed in the second quarter of 2023 and will determine the direction of the development and the future of Galileo in the coming decades. This system allows accurate positioning for European countries as well as the rest of the world. (ii) The development of the Copernicus project, a European Union programme dealing with observing Earth from space and providing data on the state of the Earth's environment as well as on climate change, natural disasters and human activity. The ESA is one of the key partners in this programme, together with the European Commission and the European Environment Agency. The Copernicus project consists of two main components: the Earth surveillance satellite system and services on the planet's surface using this satellite data. The satellite system consists of six different satellites, each of which has a special mission and capability to collect data regarding Earth. The Copernicus and Galileo programmes are of utmost importance for the development of applications in the downstream space technologies sector, and their development gives Europe a significant amount of independence from American and other similar systems. (iii) The ESA also continues the development of EGNOS (the European Geostationary Navigation Overlay Service), a system that provides a navigation signal suitable for use in aircrafts, ships, trains and other modes of transport. (iv) Research missions such as the 2018 BepiColombo mission are also important for the development of space technologies; the ESA launched the BepiColombo mission in collaboration with the Japan Aerospace Exploration Agency (JAXA) to explore Mercury, one of the least explored planets. This mission is comprised of two spacecrafts that are to be located in Mercury's orbit: Mercury Planetary Orbiter and Mercury Magnetospheric Orbiter. They will study Mercury's surface, atmosphere, magnetosphere and internal structure. (v) Euclid: the ESA plans to launch the Euclid mission in 2023 to study dark matter and dark energy in space. (vi) Space Rider: In collaboration with the Italian company Thales Alenia Space, the ESA has developed Space Rider, an autonomous spacecraft that will be able to carry cargo into orbit and then return to Earth, i.e. it will be possible to use it for multiple flights. (vii) The EAGLE-1 project: the aim of the EAGLE-1 project is to develop and launch a satellite quantum communication system, including both space and terrestrial elements, and to implement an expanded pilot campaign in orbit as well as to demonstrate quantum key distribution (QKD) across Europe, which is essential for quantum communication.

On 19 February 2018, the Government of the Republic of Croatia signed an agreement with the ESA on space cooperation for peaceful purposes. The Agreement entered into force on 8 September 2018 for a period of five years. In May 2020, the Implementing Arrangement on Technical and Professional Assistance also entered into force. The purpose of the Implementing Arrangement was to determine the scope and modalities of the assistance to be provided by the ESA to the Republic of Croatia for the implementation of one or multiple calls for project proposals in the context of space-related activities. Between December 2020 and July 2022, a total of three national calls were implemented by the Ministry of Science and Education under the Implementing Arrangement. Sixty-four project proposals were submitted and a total of thirty-four projects were approved for funding. Out of the total 34 approved project proposals, 16 are coordinated by the academic sector, while the remaining 18 project proposals are coordinated by the private sector. Croatian applicants have achieved the greatest success in the following areas: Earth Observation (16 approved projects), Space Technologies (11 projects), Space Science (4 approved projects) and Educational Activities (3 approved projects).

On 23 March 2023 in Paris, the Government of the Republic of Croatia signed the European Cooperating State Agreement between the Republic of Croatia and the European Space Agency. This agreement allows a Member State to participate in ESA programmes and activities and should be complemented by a Plan for European Cooperating States (PECS Charter).

The European Cooperating State Agreement between the Republic of Croatia and the European Space Agency supports direct cooperation between the Republic of Croatia and the European Space Agency in relation to space and space technologies. The Agreement will enable the strengthening of the cooperation between the academic and private sectors, honest and fair industrial participation in future programmes of the European Space Agency but also for the space activities of the Republic of Croatia to be in line with those of the Member States.

At the end of this introductory section, it is worth mentioning that a document titled ‘Representation of the Aerospace Sector in the Republic of Croatia’ was written at the MZO in 2018 and that it was taken into account prior to this study. In addition to that document, the relevant documents of the Slovak Republic and the Czech Republic as well as the previously conducted mapping regarding the energy area, carried out by the Institute of Economics, were also relied on in the preparation of this report. Additionally, it is also worth mentioning that the Adriatic Aerospace Association, which connects some of the stakeholders from the aerospace sector, operates in Croatia, and that there is a private initiative called CroCube (https://crocube.hr/en/) that collects donations for sending a Croatian satellite into space.

1.2. Basic Terms in the Report

Researchers in public scientific institutions and business entities (companies) are employees of these legal entities, who are engaged in research, publishing scientific papers and implementing projects in

these legal entities. The quality of research at scientific institutions and companies was evaluated by analysing three types of indicators:
(1) number of publications indexed in the SCOPUS database and number of citations standardised to the age of the publication;
(2) project activity, i.e. project management and participation; and
(3) different forms of collaboration within projects and research activities.

Mapping, in the context of this project and throughout the entire report, implies the identification of researchers and public scientific institutions as well as business entities (companies) operating in the Space Technologies area on the basis of an analysis of the scope of their activities, such as:
(1) participation in various projects within the S3 implementing policy instruments, S3 additional policy instruments as well as in selected EU programmes;
(2) number of published scientific papers (in the SCOPUS database) and citations of these papers;
(3) collaboration with other institutions;
(4) commercialisation of research results; and
(5) use of equipment supporting the work of researchers.

Projects — the subject of interest of this report is the participation of Croatian scientists and entrepreneurs in projects falling under a portion of the Smart Specialisation Strategy (hereinafter: S3) and the participation of Croatian scientists and entrepreneurs in projects under some of the EU programmes related to the topics of space technologies that are not classified under the Smart Specialisation Strategy programmes. The projects of scientists and entrepreneurs under FP7, Horizon 2020, Horizon Europe, the Croatian Science Foundation programmes as well as the projects from the programmes implemented by HAMAG-BICRO were taken into account: Knowledge-Based Companies Development — RAZUM, Research and Development Programme — IRCRO, Increasing New Product Development and Services Arising from Research and Development Activities — RDI1 and RDI2, Proof of Concept — PoC from the seventh and eighth calls, the EUREKA and EUROSTARS programmes, Innovation Commercialisation, Innovation Vouchers, Innovation at Newly Established SMEs, Integrator, Innovation in S3 and European Space Agency (ESA) projects. The aim was to identify projects where solutions within space technologies were developed but not those where finished solutions with some basic purpose were installed.

The Smart Specialisation Strategy (S3) is a strategic document that defines priority areas for stimulating investment in research, development and innovation (RDI) using public funds and is a key document for directing EU funds earmarked for this purpose. The Smart Specialisation Strategy of the Republic of Croatia was initially adopted in 2016 with the aim of using the structural funds of some of the EU funds.
The new Smart Specialisation Strategy by 2029[1] takes into account experience obtained, lessons learned and evidence available from the implementation of the Smart Specialisation Strategy 2016–2020 in order to achieve significant improvements in the next implementation cycle of the smart specialisation programme. The aim of the programme interventions planned under the new Smart Specialisation Strategy by 2029 is to improve Croatia’s overall innovation efficiency and capacities to strengthen competitiveness and promote industrial digital and green transformation.

[1] The Smart Specialisation Strategy has not yet been formally adopted.

The following is to be achieved through the three specific objectives of the Smart Specialisation Strategy[2]:

- improving scientific excellence;
- bridging the gap between the research and business sectors; and
- increasing innovation efficiency.

Under S3 by 2029, the following thematic priority areas are defined:

- Personalised Healthcare;
- Smart and Clean Energy;
- Smart and Green Transport;
- Security and Dual Use — Awareness, Prevention, Response, Remediation;
- Sustainable and Circular Food Systems;
- Adapted and Integrated Wood Products; and
- Digital Products and Platforms.

1.3. Mapping Methodology

The methodological framework for the mapping of the space technologies area was developed in several key steps.

1.3.1. Defining the Scope of the Space Technologies Area

Defining the key technologies, i.e. the engineering, scientific and computer disciplines within the field of space technologies was conducted to achieve the following objectives:
(i) build a database of institutions and researchers from the public sector and private business entities;
(ii) define the keywords (technologies, research topics, products and services) by which databases will be searched (SCOPUS, project applications for calls defined in Chapter 1.2.);
(iii) prepare an adequate survey questionnaire for primary data collection; and
(iv) create a landscape of institutions and researchers from the public sector and private business entities active in the space technologies thematic area.

In view of the above objectives, the keywords were defined in such a way as to build a database of entities with existing research and development capacities in the field of space technologies. In this context, specific technologies as well as engineering, scientific and computer disciplines and keywords for this area have been defined. During the research of secondary data, the set of keywords was tested iteratively, i.e. it was checked whether a keyword was retrieving scientific papers and/or projects exclusively related to space technologies or only partly from that area and partly from other areas. The set of keywords for the analysis of secondary data was adapted accordingly using this iterative process and the final list of keywords was established. In other words, after several iterations, the final

[2] https://mzo.gov.hr/pristup-informacijama/e-savjetovanja-koja-je-pokrenulo-ministarstvo-znanosti-i-obrazovanja-2022/zavrseno-21-prosinca-2022-o-prijedlogu-nacrta-strategije-pametne-specijalizacije-do-2029-s3/5202

set of keywords was obtained that indexed papers related to the field of space technologies. The list of keywords is presented in Chapter 2.1.

SPACE TECHNOLOGIES

Space technologies entail a number of disciplines that directly contribute to the exploration and use of space for commercial purposes. Space technologies can be classified into three groups:

- Upstream technologies used for the development, construction, launch and maintenance of space systems, including:
  - structures (launch systems, satellite systems, tanks or thermal control);
  - propulsion systems (solid, liquid, hybrid or electric propulsion);
  - load (optical and infra-red (IR) instruments, radars, telecommunications and navigation, automation and robotics or adaptive systems);
  - power supply systems (solar panels, batteries or electricity distribution);
  - mechanisms (satellite mechanisms or launcher mechanisms);
  - space subsystem control (Attitude and Orbit Control (AOCS) sensors and actuators);
  - on-board data subsystems (on-board computers, microelectronics, machine learning and artificial intelligence for on-board data);
  - communication systems (RF technology, antennas or telemetry, tracking and command systems (TT&C)); and
  - optoelectronics (optical communication, photonics, quantum technology, detector technologies or laser technologies).

- Midstream technologies that serve to establish links between space systems (e.g. functional satellites) and end users, which include:
  - terrestrial stations and operations (terrestrial stations, missions or terminals); and
  - support systems (terrestrial support equipment, data processing, data archiving or data systems).

- Downstream technologies used for the exploitation of space data and for the development and manufacture of equipment for end users, ultimately used for:
  - Earth Observation (EO);
  - GNSS (Global Navigation Satellite System), i.e. for global positioning and navigation;
  - satellite communication; and
  - the sustainability of the use of space and security in space, as well as Space Situational Awareness (SSA), which includes modelling and risk analysis, collision avoidance systems, laser satellite tracking and space debris and asteroids monitoring).

In addition to the above classification, the secondary data search and the creation of the database will use the division of the market, i.e. the various applications of space technologies, into the following areas:

- Earth observation with applications in meteorology and climate observation, climate change monitoring, sea and water observation, forests and agriculture observation, etc.; the Copernicus programme, led by the European Commission, which is one of the components of the Space Programme of the EU and the ESA, etc.;

- GNSS applications, including applications in air transport, maritime transport, vehicle control, time measurement and synchronisation as well as search and rescue applications, or general applications in the industry sector using global positioning, Galileo or European GNSS, etc.;
- services relying on satellite communications (SatCom services), broadband services, broadcasting services, telemedicine, secure communication, etc.;
- terrestrial context — Earth stations, telemetry, monitoring, management and control;
- flight operations — launch centres or launch vehicles;
- research missions — life science, microgravity and the International Space Station (ISS); and
- security in space — Space Situational Awareness (SSA), the application of collision and space debris avoidance technology or space climate monitoring.

Finally, the following engineering, scientific and computer disciplines essential for the above space technologies, or markets, were used in the search:

- engineering disciplines (propulsion systems, aeronautics, automation, robotics, space assembly, power systems, heat transport or RF systems);
- scientific disciplines and technologies (astronomy, astrophysics, space climate, the impact of space climate on Earth, optical communications, solar cells, materials science, nanotechnology, quantum technologies, cryptography, meteorology and climate observation, climate change, astrobiology, chemical reactions in space or human health and medicine in space); and
- computer disciplines (data science or artificial intelligence).

The list of all the technologies is longer, but the above selection is optimal for creating a researcher database. This area will be limited primarily to researchers and companies that **develop new space technologies or are engaged in research in** that field, i.e. have their own capacities to develop their own systems, solutions and products.

Therefore, in order to better map the potential of the Space Technologies area, this methodological approach would not include entities that use commercially obtained solutions and apply them in their activities.

<u>1.3.2. Creating a Database of Researchers in Public Scientific Organisations under the Space Technologies Area</u>

The researchers database was created by listing scientific institutions based on queries sent. The list of scientific institutions to which the query was sent was made on the basis of the secondary data collected and taking into account the professions (e.g. technical professions) present in these institutions.

<u>1.3.3. Creating a Private Business Entities Database for Space Technologies</u>

The database of private business entities was created on the basis of an analysis of the secondary data collected from the programmes to which the business entities applied in the period from 2016 to the end of 2022 and the identification of business entities through relevant associations bringing together private entities.

1.3.4. Collection of Primary and Secondary Data on Projects under the Space Technologies Area

The primary data comprises the responses of target groups (researchers and companies) collected through a survey questionnaire sent to their electronic addresses, while the secondary data was obtained from available databases of ministries, agencies and/or institutions related to different programmes in which the researchers and business entities from the target area participate.

The questionnaires were sent to all the listed researchers and business entities in the field of space technologies.

1.3.5. Analysis of Collected Data

The quantitative and qualitative data collected was processed in the following ways:

- descriptive data analysis: it involves summarising and describing the collected data (use of measures such as mean value, median, mode, standard deviation and frequency distribution);
- qualitative analysis: includes the analysis of collected non-numerical data, such as answers to open-ended survey questions (e.g. categorisation of answers and searching for patterns or topics);
- content analysis: includes the analysis of text data to identify patterns or topics as well as text machine processing techniques to recognise relevant topics; and
- inferential analysis: it involves drawing conclusions from the collected data sample.

1.3.6. Database Updates and Building the Landscape of the Space Technologies Thematic Area

- It includes an estimate of the number of active researchers, i.e. scientists and entrepreneurs, in the Space Technologies area;
- the identification of key institutions dealing with space technologies and distribution of authors by institution; and
- the distribution of research activities by types of space technologies.

2. Analysis of Secondary Data Regarding the Research and Project Activities of Croatian Scientists and Entrepreneurs in Space Technologies Topics

2.1. Approach

Croatian public higher education institutions and public scientific institutes have actively participated or are currently participating in a number of programmes for funding research, development and innovation. In carrying out this and other research, they publish scientific publications in the form of scientific and conference papers, professional papers, books, chapters in books and other forms of publications. **In this part of the analytical report, based on the available secondary data, the projects or publications related to the Space Technologies thematic area were filtered and then analysed, and the final results were presented in order to achieve the project objective.**

The first step was to select a set of programmes to be processed in this analytical report, i.e. to select a scientific publications database. The potential databases for processing scientific publications were Web of Science and SCOPUS. Since the overlap of information contained in these two databases is extremely high, the **SCOPUS** database was analysed in this report, with a restriction to the period of the last 10 years (2012 –2022), depending on the available data.

This chapter analyses the activity of Croatian researchers in the following EU programmes:

- Seventh Framework Programme for Research and Technological Development (FP7);
- Horizon 2020; and
- Horizon Europe.

Furthermore, the contracted projects of the Croatian Science Foundation, as well as the projects and project applications submitted to calls by the Croatian Agency for SMEs, Innovation and Investments (HAMAG-BICRO) were also analysed. Specifically, the following calls were analysed:

- Knowledge-Based Companies Development — the RAZUM programme in 2015;
- Research and Development Programme — the IRCRO programme in 2015;
- the Increasing New Product Development and Services Arising from Research and Development Activities programme — RDI1 and RDI2;
- the Proof of Concept programme or PoC (seventh and eighth calls);
- the Innovation in S3 Areas programme;
- the Innovation Commercialisation programme;
- the Integrator programme;
- the Innovation Vouchers programme;
- the Innovation at Newly Established SMEs programme — 2019;
- the EUREKA programme; and
- the EUROSTARS programme.

Finally, the projects submitted following the call by the European Space Agency (ESA) and implemented in cooperation with the Ministry of Science and Education were analysed:

- European Space Agency (ESA) projects.

This selection of co-financing programmes is a comprehensive framework as the vast majority of Croatian researchers, scientists and entrepreneurs who were active in projects under the Space Technologies area participated in the above mentioned programmes. The term *active* means a researcher who has participated in an approved or submitted project as a principal researcher or research associate.

The method of selecting the scientific papers, i.e. projects, falling within the thematic area was implemented using an appropriate set of keywords. The keywords used to filter data related to space technologies are given in Table 1. The keywords were chosen using an iterative process. In the first iteration, a large set of keywords was selected which, in addition to those listed in Table 1, contained words such as downstream, midstream, upstream or LEO (an acronym for Low Earth Orbit). All papers from the period between 2012 and 2022 with at least one address (affiliation) being from the Republic of Croatia were then filtered out. From these papers, a table with the names of the authors, their affiliations and keywords mentioned in their papers was derived. Then, for each keyword, the sample of authors and their papers was analysed to see if the keyword included papers from the field of space technologies or also papers from a different field. This is because some keywords related to space technologies also appear in completely different fields.

For example, the word downstream is associated with space technologies, but is also a common term in scientific papers in biology that are not related to space technologies. Therefore, this word is not a good keyword for selecting papers regarding space technologies. With words such as downstream that would retrieve papers that do not fall within the thematic area, the word was either modified (e.g. the word robotics was expanded to be robotics and space) or was completely removed from further analysis (e.g. downstream, midstream, upstream or GPS).

After several iterations, the final set of keywords was obtained that indexed papers related to the field of space technologies. The final set of keywords, yielding a high-quality and comprehensive signal, is given in Table 1.

Table 1 — Keywords used to filter the databases for the field of space technologies. The keywords in the table's left column are in English, while the right column contains these keywords translated into Croatian.

space tech	*svemirska tehnologija*
space science	*znanost o svemiru*
satellite	*satelit*
payload	*korisni teret*
aeronautics	*aeronautika*
launch vehicle	*lansirno vozilo*
space transportation	*svemirski prijevoz*
global positioning system	*globalni sustav pozicioniranja*
GNSS	*GNSS*
SatCom	*SatCom*
satellite communication	*satelitska komunikacija*
Earth observation	*promatranje Zemlje*
Galileo	*Galileo*
Copernicus	*Kopernik*
robotics AND space	*robotika i svemir*
optoelectronics	*optoelektronika*
photonics	*fotonika*
quantum tech	*kvantna tehnologija*
quantum communication	*kvantna komunikacija*
space safety	*sigurnost u svemiru*
space situation awareness	*svijest o situaciji u svemiru*
low Earth orbit	*niska Zemljina orbita*
space climate	*svemirska klima*
space weather	*svemirske meteorološke pojave*
space debris	*svemirski otpad*
spacecraft	*svemirska letjelica*

A visually attractive yet informative display is the keyword cloud and the network of words that are associated with them. This keyword cloud, where the size of a word corresponds to its frequency in the SCOPUS database, is shown in Figure 1. From this image, it is concluded that the words GNSS, positioning, global and navigation are frequently appearing words, which tells us about the prevalence of research in downstream technologies.

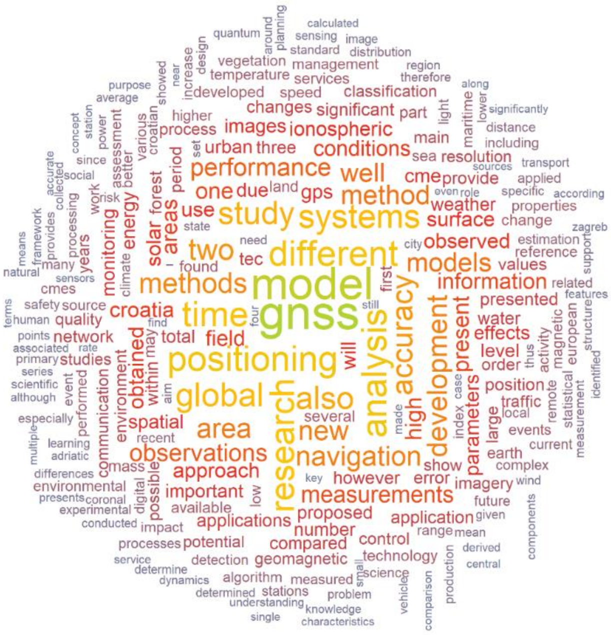


Figure 1 — A cloud display of keywords and words associated with them in the papers. The number of repetitions, i.e. frequency, is proportional to the font size in the display.

2.2. Research Activities: Overview of Scientific Publications Related to Space Technologies Topics in the SCOPUS Database

Croatian public higher education institutions and public scientific institutes participate in the development and application of space technologies. Figure 1 shows the number of publications by Croatian researchers indexed in the SCOPUS database in the field of space technologies in the period between 2012 and 2022 retrieved by using the keywords defined above. It is necessary to clarify that the SCOPUS database contains papers by researchers from public scientific institutions but also those by researchers from private companies. In the chapter on the SCOPUS database, in addition to the word researchers, the words authors or scientists and entrepreneurs are also used, bearing in mind the stated fact.

Publications in the SCOPUS database include scientific papers, conference papers, book chapters, review papers, editorial reviews and other types of publications. Of the data in the database, the title of the publication, the summary of the publication and the keywords that can be found annotated for each publication in the database was the data taken into consideration. If one of the keywords defined in Table 1 appeared in the title, summary or annotated keywords, the publication was taken into account. Only publications where at least one affiliated institution had its address in the Republic of Croatia were taken into account.

Authors or related institutions (public institutions and private entities) with Croatian addresses were retrieved from publications related to space technologies via keywords. In this way, all the authors from the Republic of Croatia with at least one publication in the past 11 years that mentions a keyword related to space technologies were found. Such a procedure ensured that all the authors publishing in this field were identified. Figure 2 clearly shows that the number of publications has largely been growing over the years. Based on the number of papers in the last two years, it can be concluded that saturation has likely taken place. Specifically, the number of papers from 2021 is slightly higher than that from 2022. Whether this trend of 150 papers per year will be maintained or whether there will be growth depends on the further development of this sector in the Republic of Croatia.

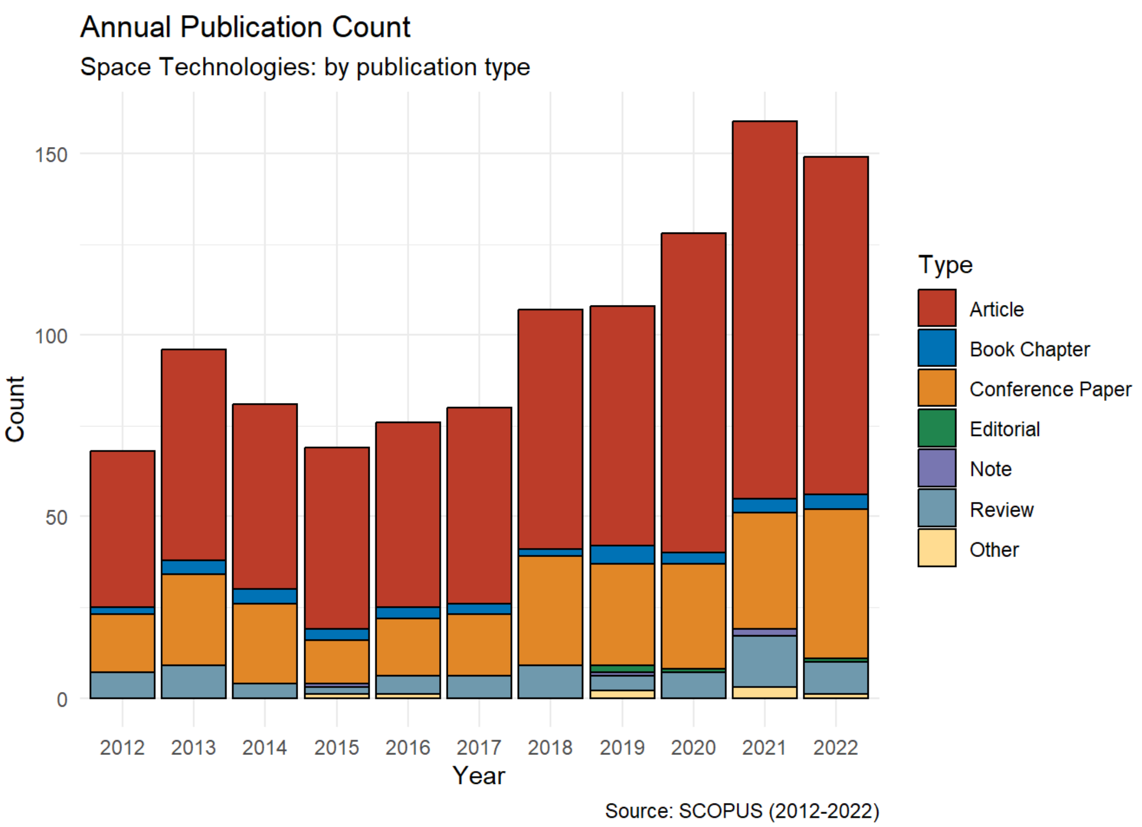


Figure 2 — Number of publications by Croatian scientists and entrepreneurs in the field of space technologies from 2012 to 2022. Different colours are used for scientific papers, books, chapters in books, conference papers, editor letters, letters, review papers and corrections.

Figure 3 shows the number of publications from the field of space technologies from 2012 to 2022, divided by scientific field. In other words, all papers from a period of 11 years that fall within a scientific field, for example engineering, are shown. The fields are classified according to the All Science Journal

Classification Codes (ASJC) scheme. The highest number of publications was in the field of Earth and planetary sciences and engineering, while physics and astronomy followed by materials science rank third and fourth, respectively.

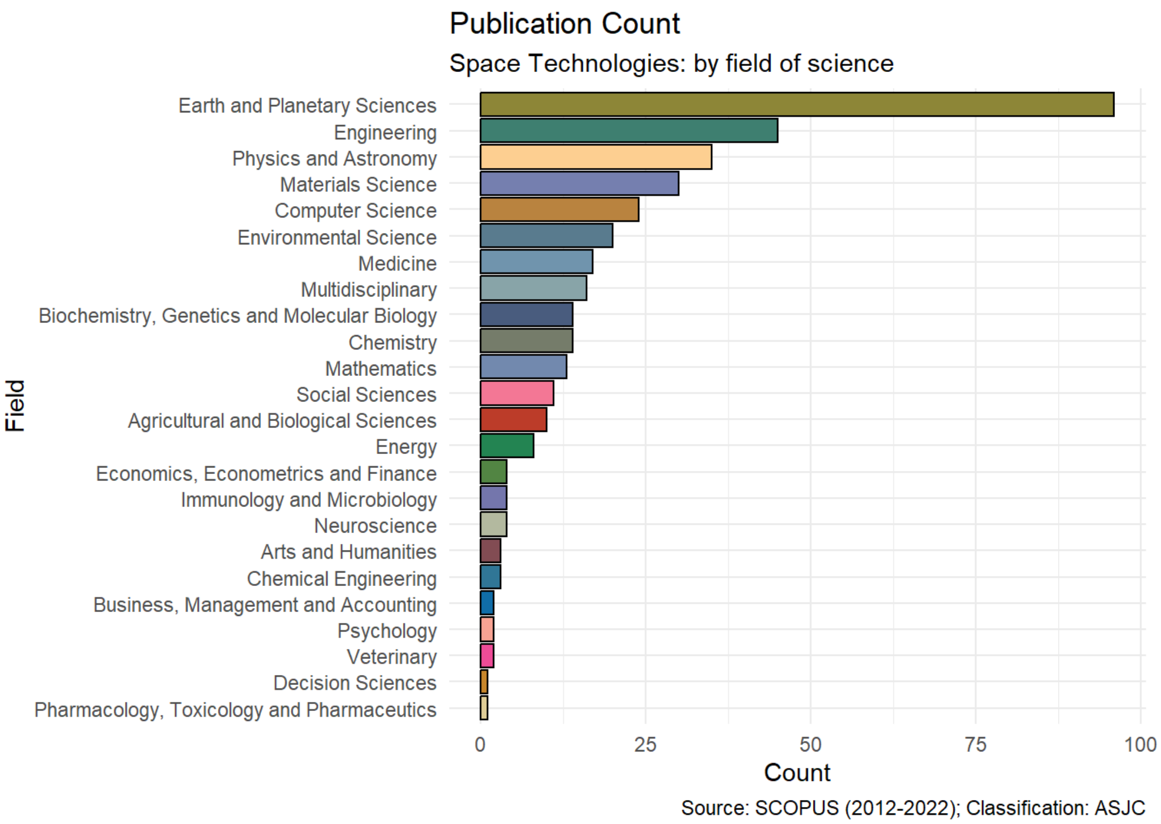


Figure 3 — Number of publications on space technologies from 2012 to 2022, by scientific field.

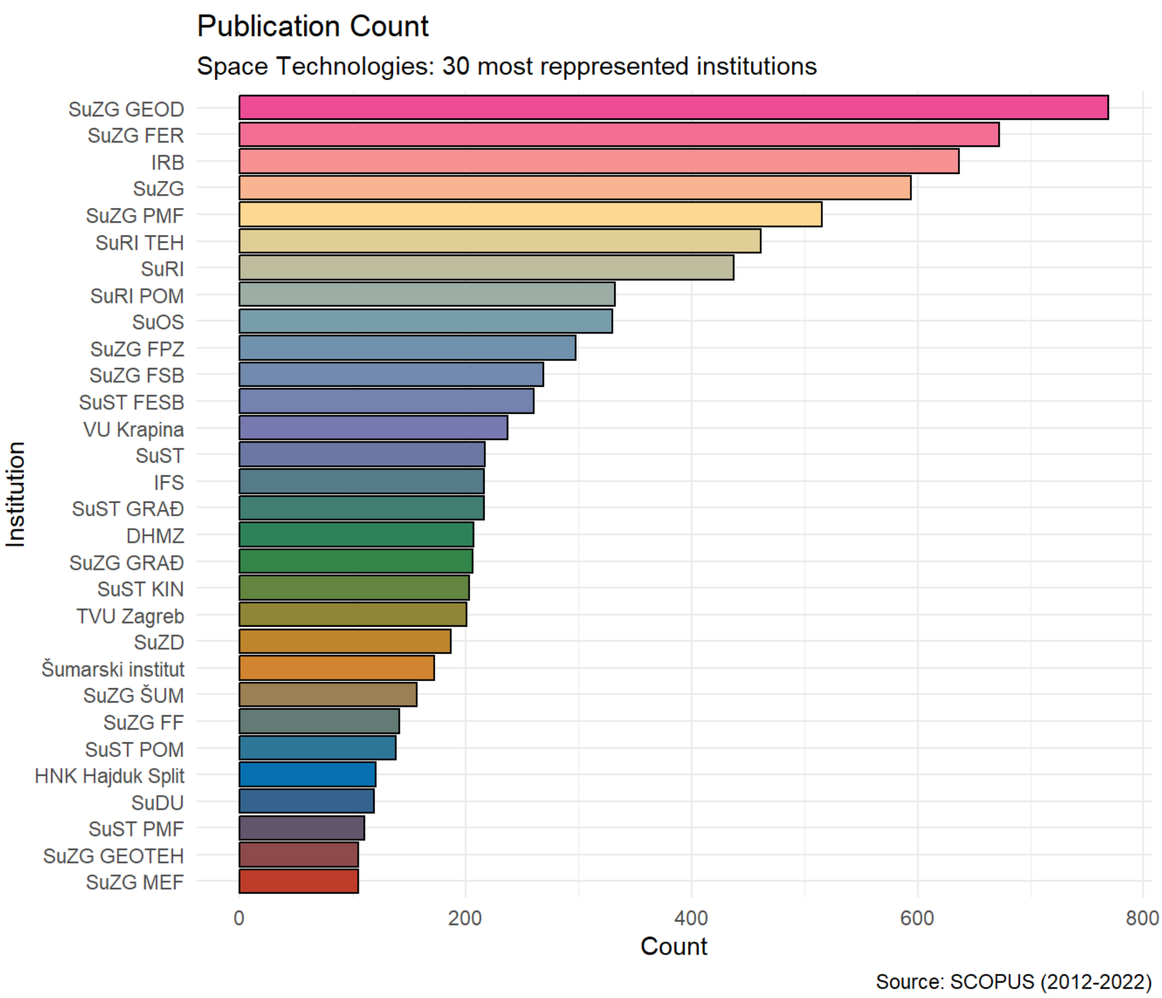


Figure 4 — Number of publications on space technologies from 2012 to 2022 for the 30 institutions with the highest number of publications found in the database.

Figure 4 shows the number of publications on space technologies between 2012 and 2022 for different institutions. In this way, one can see which public scientific institutions or companies are most active in this field, i.e. where the critical mass of researchers dealing with topics related to space technologies can be found. From the figure, it is evident that the Faculty of Geodesy of the University of Zagreb is the leading institution. This result can be explained by taking into account that Hvar Observatory falls under this faculty (https://www.geof.unizg.hr/opservatorij-hvar/) and that the Faculty of Geodesy of the University of Zagreb is one of the project holders for the project of the European Space Agency. Ruđer Bošković Institute and the Faculty of Electrical Engineering and Computing of the University of Zagreb are next in order, followed by the University of Zagreb, i.e. the Faculty of Science of the University of Zagreb. It should be noted that Croatian scientists unfortunately do not uniformly record their affiliations in their scientific papers, so databases sometimes classify them only under the University of Zagreb without citing the specific faculty, so the University of Zagreb appears as the only legal entity in one part of the secondary data. However, all of these papers were produced at one of the constituent faculties.

High-quality information can also be obtained by analysing the frequency of keywords in publications, as shown in Figures 5 and 6. In fact, this distribution provides information about which fields of space technologies our institutions are involved in working on. Of the keywords, the first in terms of frequency is the word satellite, while space science, GNSS and Earth observation are also very frequent. From the ranking of the keywords, it is concluded that the academic community uses and develops downstream space technologies, but there are also keywords associated with upstream technologies (quantum communication, photonics or robotics). More precise information can be extracted by interpreting the secondary data in correlation with the primary data.

Figure 6, which shows the frequency of keywords by year, shows that there is no significant trend in terms of an increase or decrease in the frequency of some of the keywords. From this data, it can be concluded that no field of space technologies has seen dramatic growth or decline compared to others over the last 11 years, at least as far as publications are concerned.

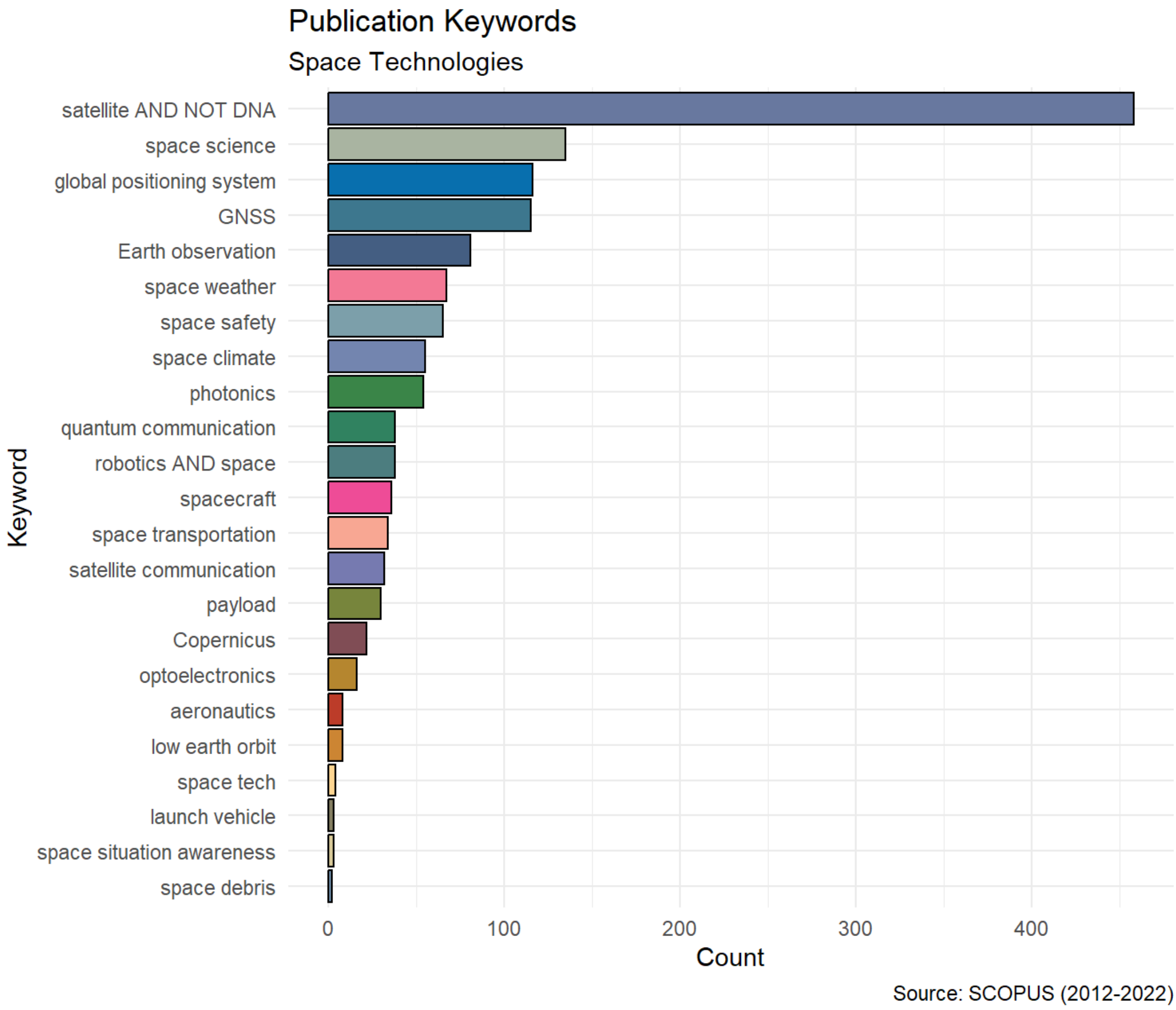


Figure 5 — The frequency of keywords in publications. The number of publications containing a specific keyword is shown; e.g. GNSS is mentioned in approximately 120 papers. Most publications contain the keyword satellite, followed by space science, global positioning system and GNSS.

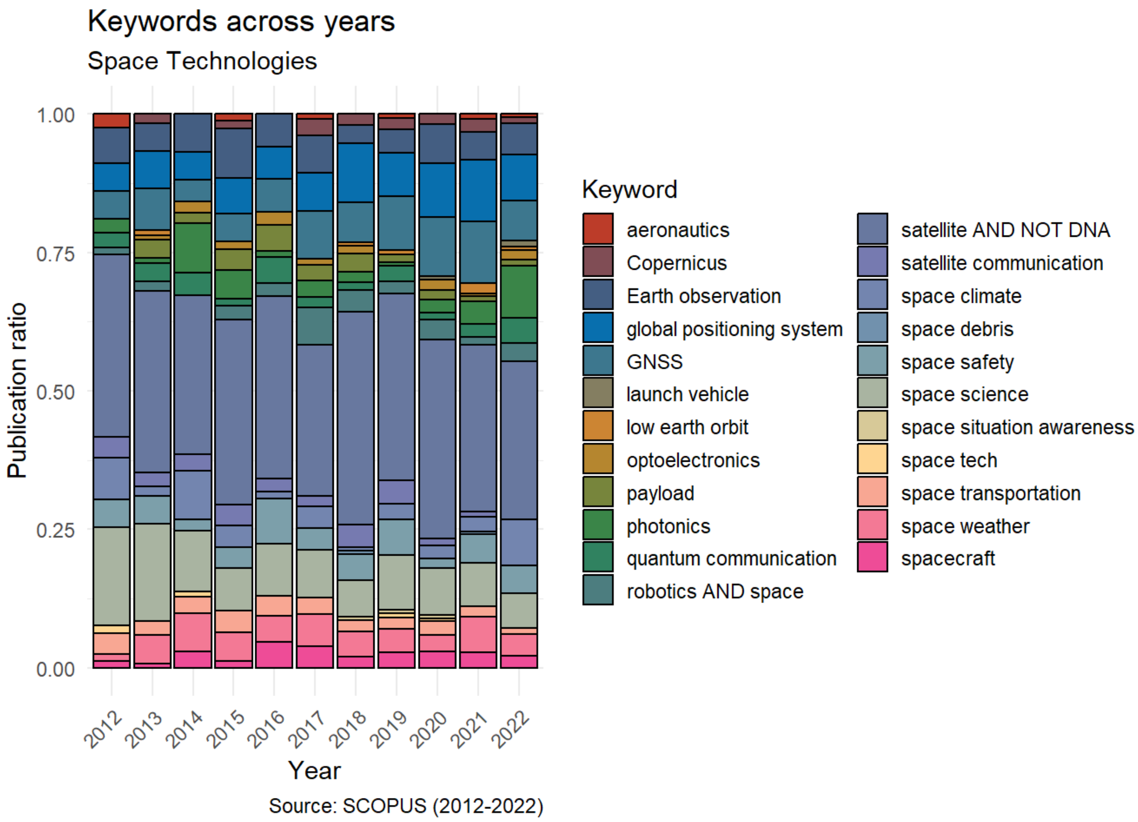
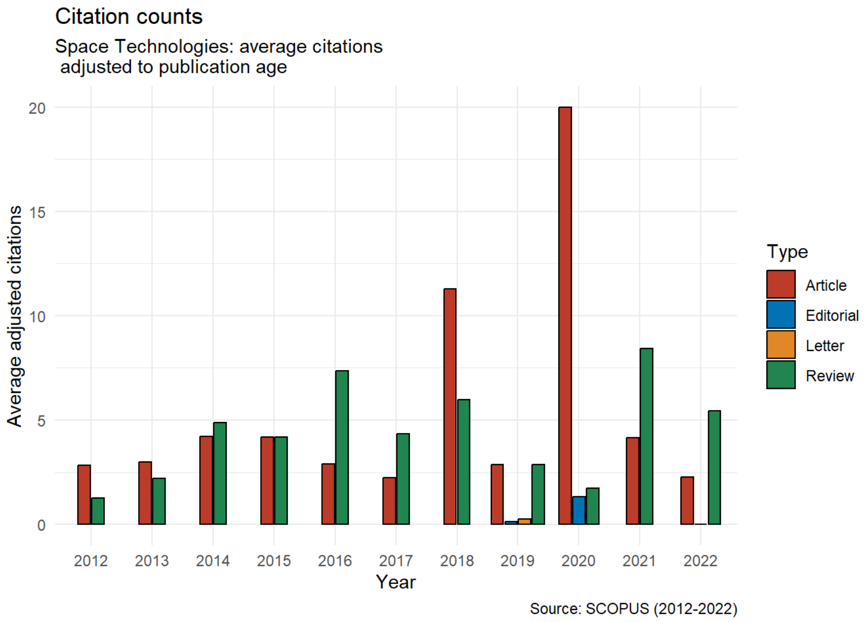


Figure 6 — Keywords and their incidence from 2012 to 2022.

The number of publications and the number of authors tells us about the prevalence of space technologies in research where the researchers have a Croatian address. However, the number of publications does not indicate directly what influence Croatian authors have on the development of this scientific field globally. This information is provided by citation data. Citation data tells us how papers by Croatian authors are received internationally, i.e. how many other authors rely on the work of our scientists and entrepreneurs. If a paper has a very low number of citations, it does not have a major impact on the development of a scientific field. Figure 7 (top) shows the citation data for publications from 2012 to 2022 adequately standardised to the age of the publications (it is to be expected that older publications are cited more than newer ones), while Figure 7 (bottom) shows the average number of citations classified according to keywords and standardised to the age of the publication. Standardisation to the age of a publication means the following: for a given scientific paper, the total number of citations is divided by the number of years gone by from the date of publishing until today. Figure 7 (top) shows that the citation rate of the papers is relatively low, except for a notable increase in 2020, which to some extent indicates that there is room for improvement in the quality of research. Figure 7 (bottom) shows that the most internationally visible research is in optoelectronics, followed by research that mentions the keywords space debris, i.e. addresses the problem of space waste. There is also significant visibility of research in Earth observation and space climate. From this, one can conclude that we have internationally visible authors from the fields of both upstream and downstream technologies.



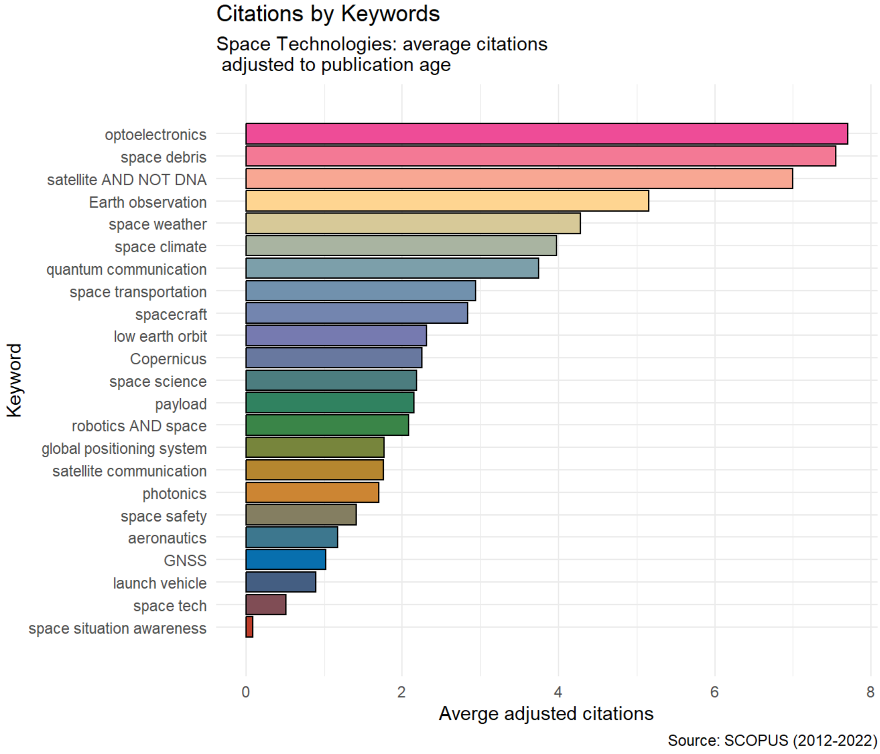


Figure 7 — Publication citation data. *The top figure shows the citation data for publications from 2012 to 2022, standardised to the age of the publication, while the bottom figure shows the average citation rate for the field of space technologies classified according to keywords and standardised to the age of the publication.*

In conclusion, in order to map the potential of Croatian public scientific institutions in the field of space technologies, Figure 8, which shows the number of scientists working in this field by institution, is particularly important. In it, the number of scientists indicates the number of persons who have at least once published at least one paper that contains at least one keyword with the affiliation of a given institution. In addition to permanent placement employees, this also includes students, doctoral students, postdoctoral students, external associates, etc., i.e. persons who are currently not working at a given institution because they have gone to another position.

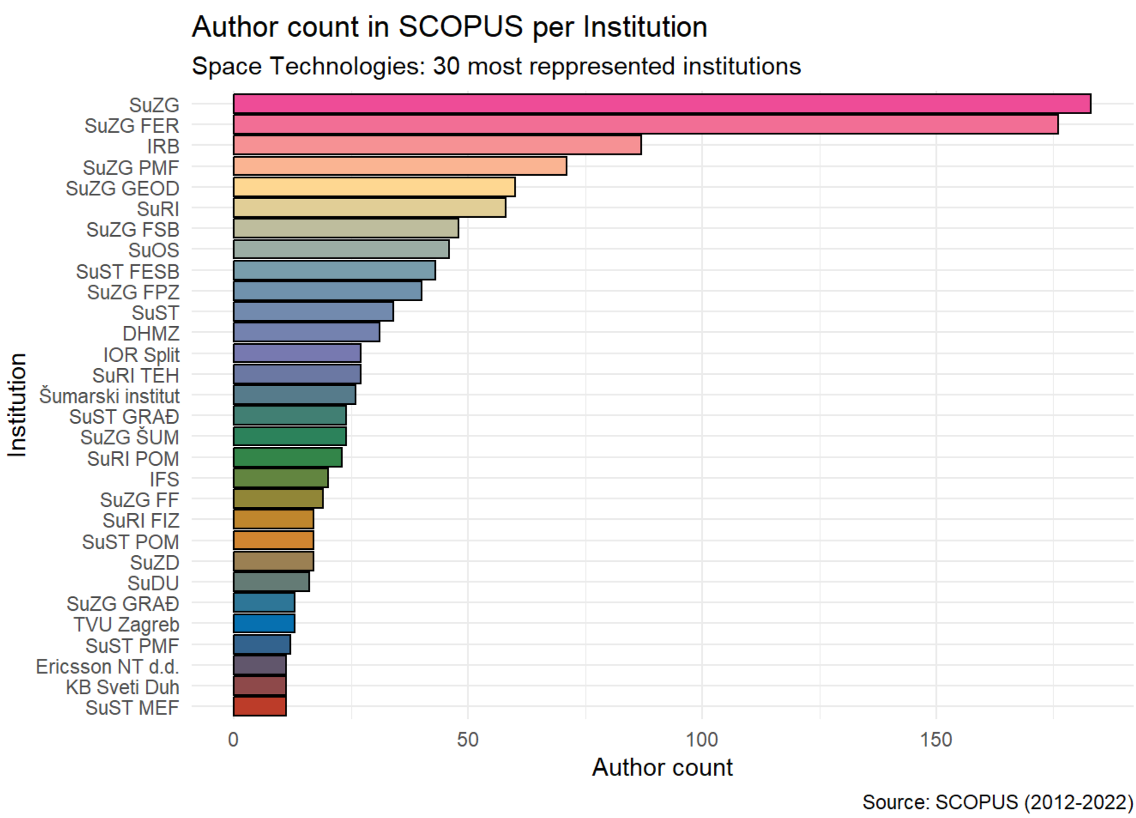


Figure 8 — Number of authors, by institution, who published papers in the SCOPUS database in the period between 2012 and 2022 containing at least one of the keywords.

The leading institutions were the University of Zagreb, within which the most represented institution was FER with more than 150 scientists, the Ruđer Bošković Institute with about 90 scientists and the Faculty of Science in Zagreb with about 75 scientists. A total of 1,476 names of authors were filtered from the secondary data. This number needs to be interpreted as the upper limit because it includes each and every author who published, within the eleven-year period, at least one article with at least one keyword within the title, summary or list of keywords. Furthermore, for the correct interpretation of these figures, it is necessary to take into account that this is cumulative data for a period of 11 years (and so includes scientists who have retired as well as graduates and doctoral students who have completed their theses and work at other institutions or companies).

In order to more precisely estimate the exact number of scientists in this field and thus **taking into account only those authors with papers containing at least two keywords, a figure of 392 active researchers in the field of space technologies for the period of 11 years is obtained.** Taking into account that the average working life is about 40 years and assuming a uniform distribution of scientists and entrepreneurs by generation, it can be estimated that in the 11 years, about 25% of these authors have retired, so around $0.75 \times 392 = 294$ scientists and entrepreneurs are currently active. The exact number of authors (the lower and upper limits) was estimated and is commented on in the conclusion to this document, taking into account the primary data. Given that, for the purposes of collecting primary data, the administrations of public institutions identified the scientists from the public sector working in the field of space technologies while also working at those institutions, the lower limit for the number of scientists was obtained after the survey questionnaires were processed. On the other hand, as already mentioned, the secondary data yielded the upper limit.

2.3. Overview of Participation of Croatian Scientists in Selected Programmes Related to Space Technologies

Horizon 2020

Horizon 2020 (H2020) is the European Union's research and innovation programme for the period from 2014 until 2020. The programme was conceived as an instrument to strengthen the competitiveness of the EU through support for research, development and innovation. The aim of the programme is to provide funding to support excellence in research, strengthen European industry and address societal challenges. Horizon 2020 had a budget of almost EUR 80 billion. The programme is divided into three main priority areas: (i) excellent science, (ii) competitiveness of European industries and (iii) societal challenges. Climate change, health and well-being, energy, transport, food security, digital technologies (including artificial intelligence) and space technologies are some of the areas highlighted under the programme. The current Horizon Europe programme succeeded Horizon 2020.

This section analyses the submitted and contracted Horizon 2020 projects in the Republic of Croatia. The secondary data available for this study contained all the submitted projects, their titles and summaries as well as their associated institutions. Furthermore, it contained information on whether the institution was the main beneficiary or a partner on the project and whether the project was ultimately accepted for funding and contracted. Using the keywords, all the project applications related to space technologies under this programme were identified. If the keyword was in the title or summary of the project or project application, then it was concluded that the project belonged to the field of space technologies. Figure 9 shows the number of all the applications classified by institution, and the contracted projects are marked in blue.

A total of **139 project applications related to space technologies** were identified, **23 of which were contracted**; the success rate of the applications was slightly higher than 16%, which is above the average for H2020 applications. On the 23 projects contracted, **10 partners were from public institutions (public higher education institutions, public institutes, ministries, etc.), i.e. 43%, while the beneficiaries of 14 of the contracted projects were entrepreneurs from Croatia**. Out of the 23 contracted projects, **Croatian organisations were the coordinators,** or the main beneficiaries, **on 3 of them**. The coordinating organisations were Amphinicy d. o. o. on two of the projects and the Ruđer Bošković Institute on one of the projects.

The first four spots in terms of applications were occupied by the Faculty of Electrical Engineering and Computing of the University of Zagreb (SuZG FER), the Ruđer Bošković Institute (IRB), Amphinicy d. o. o. and Hipersfera d. o. o. (see Figure 9). Since this programme lasted for seven years, it is evident that the average number of applications related to space technologies by the leading public scientific institutions from the Republic of Croatia to this programme was two to three applications per year.

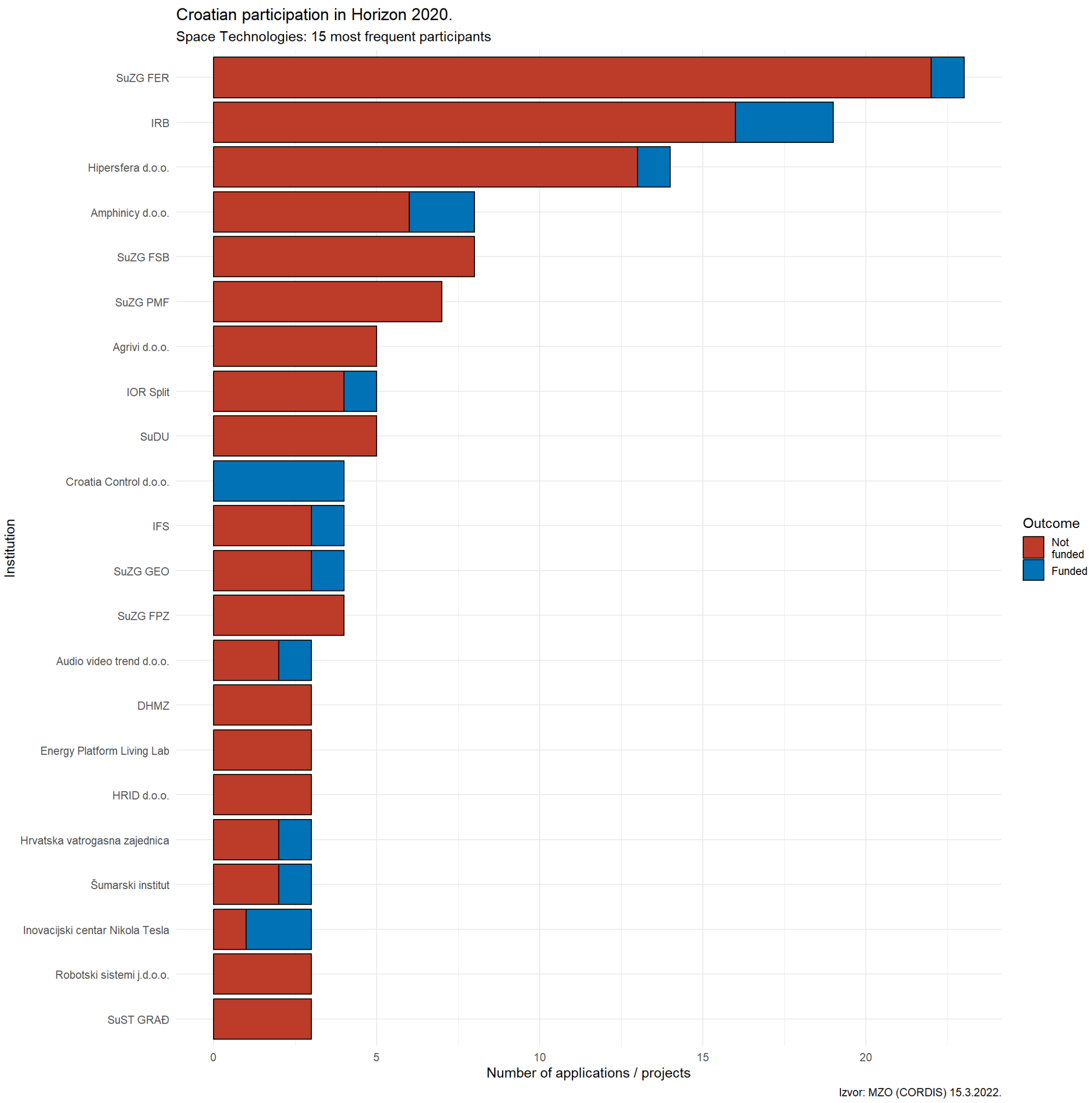


Figure 9 — Number of Horizon 2020 project applications classified by institution. Successful project applications are marked in blue and the unsuccessful ones are marked in dark red.

Figure 10 shows the number of Horizon 2020 applications divided by specific objective. It is evident that most applications related to space technologies fall under the specific objective *competitive industries (space)*, followed by the specific objectives *climate and the environment*, *competitive industries (ICT)* and the *Marie Skłodowska-Curie* (MSC) projects, i.e. outgoing and incoming scholarships.

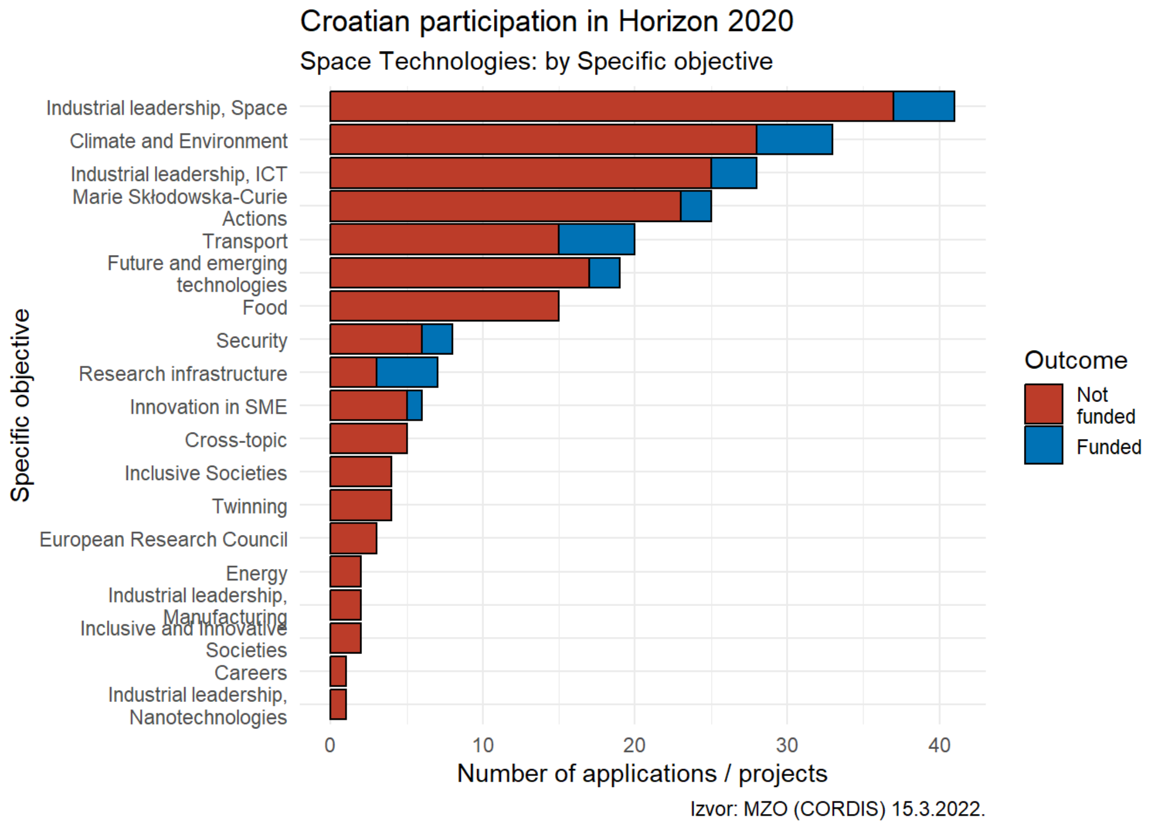


Figure 10 — Number of Horizon 2020 project applications classified by specific objective. Successful project applications are marked in blue and the unsuccessful ones are marked in dark red.

FP7 and Horizon Europe

The FP7 programme, i.e. the Seventh Framework Programme for Research and Technological Development of the European Union was implemented from 2007 to 2013 with a budget of EUR 50.5 billion, while Horizon Europe is the EU research and innovation programme to be implemented from 2021 to 2027, with a budget of EUR 95.5 billion. The secondary data available for these two programmes did not include unsuccessful project applications but only the successful (contracted) ones. More specifically, the titles and summaries of the contracted project applications, the associated institutions and information on whether the institution was the main beneficiary or a partner on the project was the data that was available.

Since the number of contracted projects proposed by Croatian scientists relative to the total number of contracted projects within the mentioned EU programmes is relatively small, and since the secondary data collected for the FP7 and Horizon Europe programmes has the same structure, they are presented here in parallel. This display also provides a visual comparison of the applications over more than six years, which was the duration of Horizon 2020.

The aim of the FP7 programme, i.e. the 7th Framework Programme for Research and Technological Development, was to foster scientific research and development projects in Europe. Its aim was to boost research and innovation in several key areas, including information and communication technologies, health, the environment, energy and transport. FP7 was the largest R&D programme in Europe, with a budget of EUR 50.5 billion. In total, more than 7,000 projects were funded.

Under the **FP7 programme, a total of 14 projects that can be classified under space technologies were contracted**. On all of the projects, Croatian institutions were only partners.

FP7 was later replaced by Horizon 2020 and then Horizon Europe.

In relation to the thematic area addressed here, Horizon Europe funds space technologies and space research under the Digital, Industry and Space objective, under Pillar 2 of the programme. Space research can also possibly be funded under Pillar 1, under Excellent Science through research projects and under Pillar 3, under Innovative Europe through innovation activities. Funding will relate to the various aspects of space research, including the development of space technologies, exploration of planets and other celestial bodies, space environment research, space observation and communication technologies as well as the development of new applications and services based on space data.

As Horizon Europe is still current, the data refers to the period until April 2023. Under Horizon Europe, a total of five projects that can be classified under space technologies were contracted. Croatian institutions were partners on all of the projects. Since the Horizon Europe programme has only been active for two years, assuming the same rate of contracted projects in the future, it can be projected that Croatian institutions and companies will contract a total of 15–20 projects. Specifically, Horizon Europe runs from 2021 to 2027, so we can approximate as follows: 5 projects / 2 years × 7 years = 17.5 projects. However, given the increasing use and availability of space technologies, especially for downstream applications, this number is likely to be even higher. This is an increase by a factor of two when compared to FP7.

Figure 11 shows the number of all contracted projects classified by organisation, with the contracted FP7 projects marked in dark red and Horizon Europe projects marked in blue. This figure shows which organisations were the most active in attracting project funding during the duration of the FP7 programme and which ones have been active so far in Horizon Europe, which is still ongoing.

Under the FP7 programme, the Faculty of Electrical Engineering and Computing of the University of Zagreb stands out. Of the private companies, Geo Sat d. o. o. and Photon d. o. o. were included in the programme. Most of the projects were implemented within public institutions, while the two private companies participated in the projects.

Within the Horizon Europe programme, the number of participants from the private sector was 80%, i.e. four projects were implemented in the companies Rinigard d. o. o., Multione j. d. o. o., Geolux d. o. o. and Hipersfera d. o. o., while one was implemented within the civil society organisation Odraz — Sustainable Community Development.

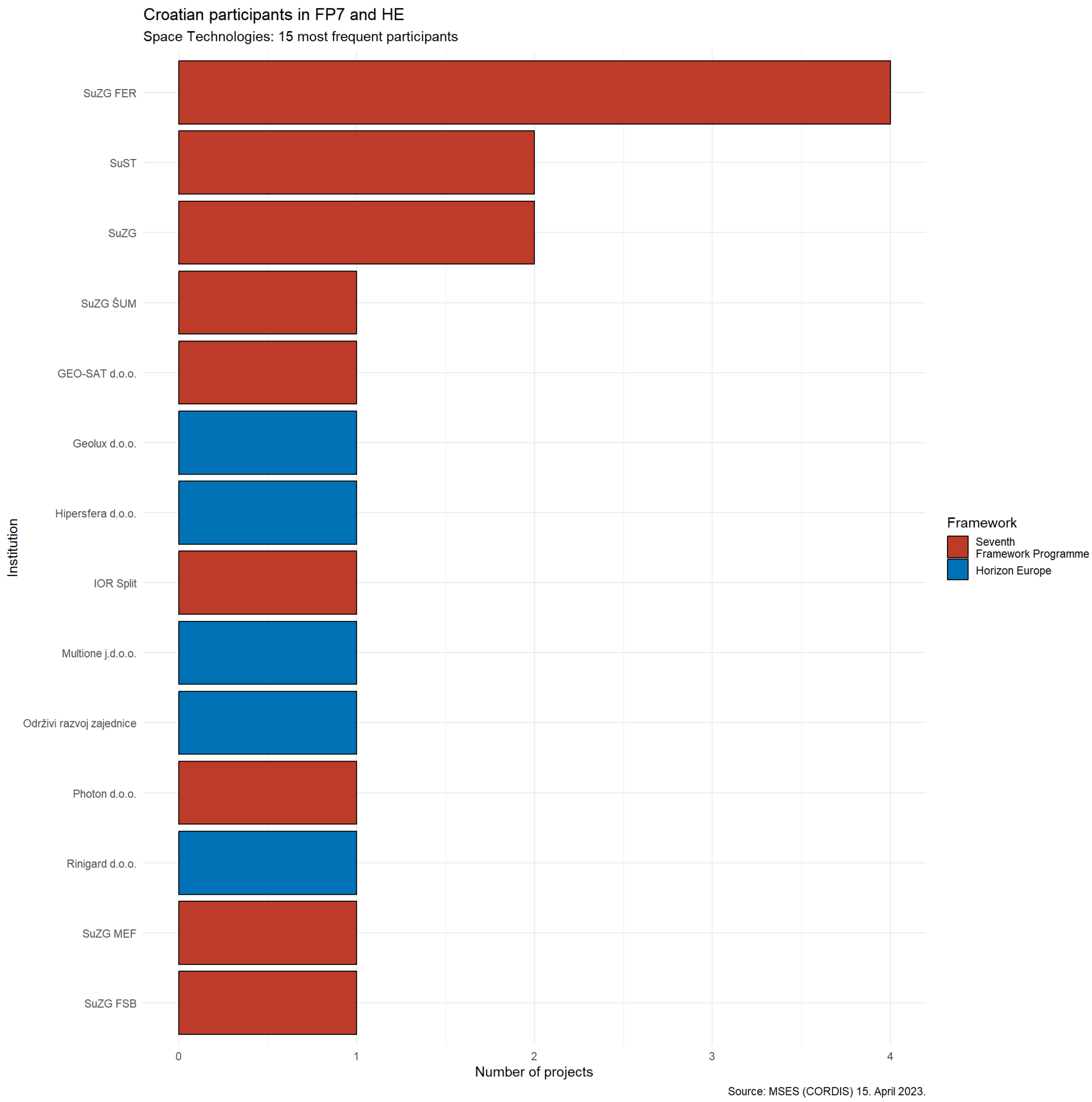


Figure 11 — Number of all contracted projects in the field of space technologies classified by institution. The contracted FP7 projects are marked in dark red and the contracted Horizon Europe projects are marked in blue.

Figure 12 shows the number of projects classified by specific objective. The contracted FP7 projects are marked in dark red and the contracted Horizon Europe projects are marked in blue. This chart provides information on which research topics are most common in this field. It is evident that, under the FP7 programme, the most common topics were the environment and space, while, at least so far, under Horizon Europe, the most common topics were food, the bioeconomy, natural resources, agriculture and the environment. For interpretation purposes, it is also important to note that the number of contracted projects is low, so any fluctuations are not negligible in relation to the main signal.

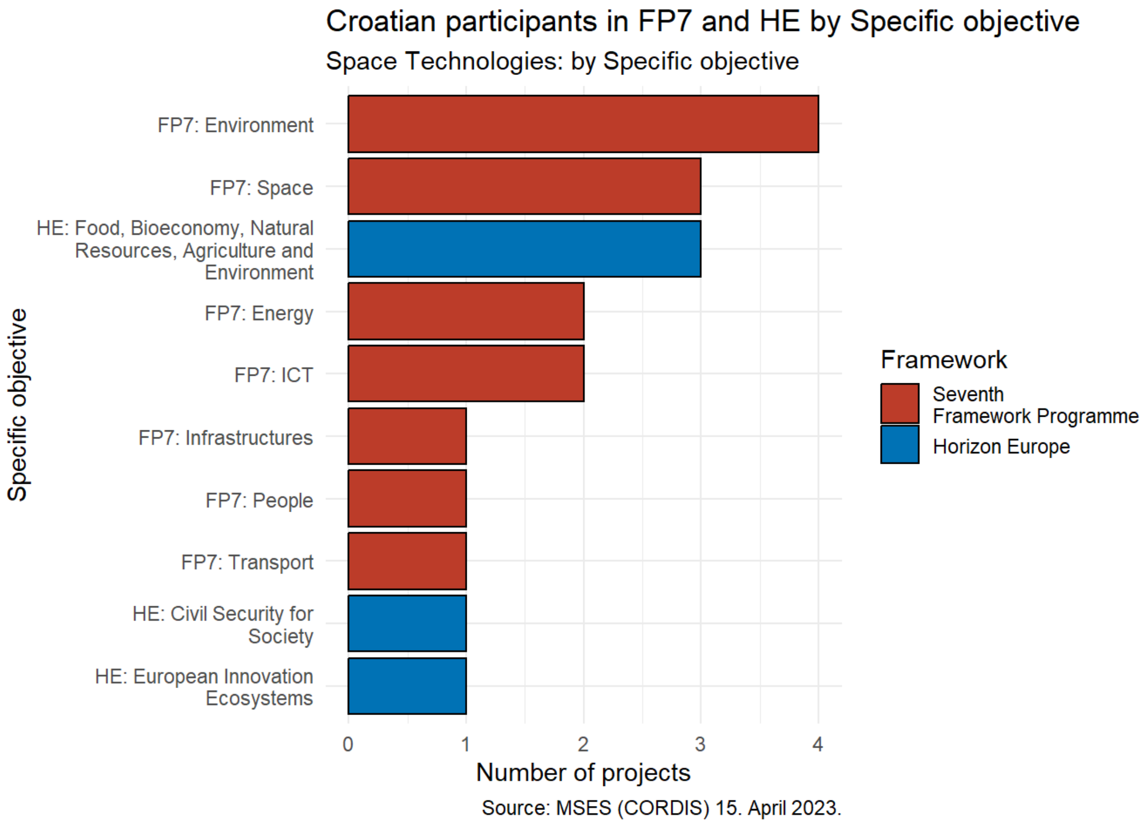


Figure 12 — Number of projects in the field of space technologies classified by specific objective. The contracted FP7 projects are marked in dark red and the contracted Horizon Europe projects are marked in blue.

CSF

The Croatian Science Foundation (CSF) is the central organisation for funding science in all scientific fields in the Republic of Croatia. The Croatian Science Foundation is an independent non-profit organisation that provides financial support for the implementation of scientific projects according to the criteria of scientific excellence. The Foundation was founded to promote science, higher education and technological development in the Republic of Croatia and to support scientific, higher education and technology programmes and projects, with the ultimate goal of ensuring sustainable social and economic development while encouraging employment based on the principles of social inclusion.

Since its founding, the Foundation has funded competitive scientific, development and innovation projects. Legal amendments from 2009 and 2012 (NN 78/2012) started a new chapter in the work of the Foundation because, in 2013, it took over the funding of national research projects from the

Ministry of Science and Education, and in 2014, also the funding of career advancement for young researchers.

An important programme implemented by the CSF is the Research Projects programme (RP). This programme has funded fundamental research that creates new and enhances existing knowledge in a specific field, but also applied research with clear technological, economic or societal objectives. The projects were contracted for a period of four years. Between 2013 and today, six calls for tenders have been published, funding more than 700 projects.

The CSF also implements the Establishing Research Projects programme (ERP) aimed at young scientists for the establishment of new research groups. The term *young scientist* means a researcher who has obtained a doctorate in science at least two years but not more than seven years prior to the deadline for applying to a call, and who wishes to set up or develop a new research group and become an independent researcher.

The research projects implemented the Programme for Stimulating Research and Development Activities in the Field of Climate Change and two thematic calls for tenders regarding the coronavirus pandemic.

The Career Advancement for Young Researchers programme aims to create a stable funding programme for young researchers at the doctoral and postdoctoral levels in all scientific fields. Under the Training of New Doctors of Science programme, six calls for tenders have been published between 2013 and today (in the figures, these projects are labelled simply as Doctoral Students) which gave more than 900 scientists the opportunity to recruit young researchers.

Under the International Cooperation programme, the goal of the CSF is to enable scientists to engage in mobility and international cooperation, and not necessarily just scientific cooperation, but also the development of the economic sector outside the borders of the Republic of Croatia.

For this mapping, the data available were the titles of the contracted projects, the summaries of the contracted projects, the researchers and the institutions from which these projects came from as well as which of the CSF programmes the projects belonged to. In the first round of the analysis of the secondary data, using the keywords defined above, the projects belonging to the field of space technologies were filtered out. Subsequently, the results obtained were manually reviewed to see if the keywords signalled some projects outside the field (e.g. the keyword *satellite* can occur in the phrase *satellite DNA*, belonging to biology rather than space technologies). These projects unrelated to space technologies were excluded from the analysis. Based on the charts obtained, the aim was, among other things, to get an insight into how active the scientists working in space technologies were, as well as the key institutions where there was activity in this field.

Figure 13 shows the number of projects in the field of space technologies over the years (from 2014 to 2022 in line with the programme). Research projects and projects aimed at doctoral students were prevalent. Research projects were more prevalent between 2014 and 2020, followed by projects aimed at doctoral students in the period from 2018 until today. The reason for this is the pattern of publishing the calls for tenders by the CSF, since the projects for doctoral students chronologically followed the research projects. In 2022, a lower number of calls for tenders were published, so a lower number of projects were contracted in total.

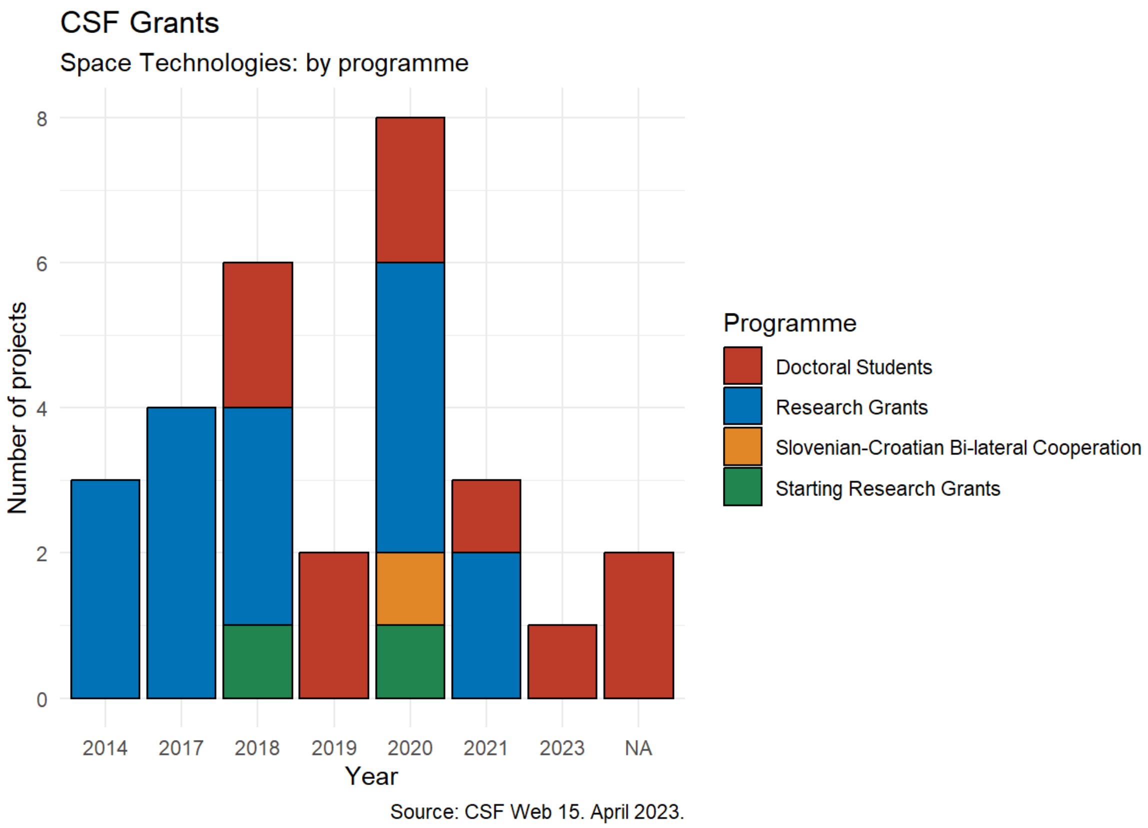


Figure 13 — Number of projects in the field of space technologies under different CSF programmes over the years. Each project is listed only once in the year in which it was contracted. In the years not seen on the chart, there were no contracted projects related to space technologies. NA refers to those contracted CSF projects for which the available data did not indicate the starting date of the contract.

Figure 14 shows the distribution of projects in the field of space technologies by scientific field. The highest number of projects was in physics, followed by electrical engineering, geodesy, forestry and mechanical engineering. In physics, these are projects related to space science (e.g. to the Sun and stars) and upstream technologies, such as quantum communication and photonics. The Platform for Satellite Measurement of Electromagnetic Radiation project, which is classified under downstream technologies, stands out in the field of electrical engineering. The fields of geodesy and forestry include projects where downstream technologies are used to conduct scientific research (e.g. satellite images of forested areas are used for analysis).

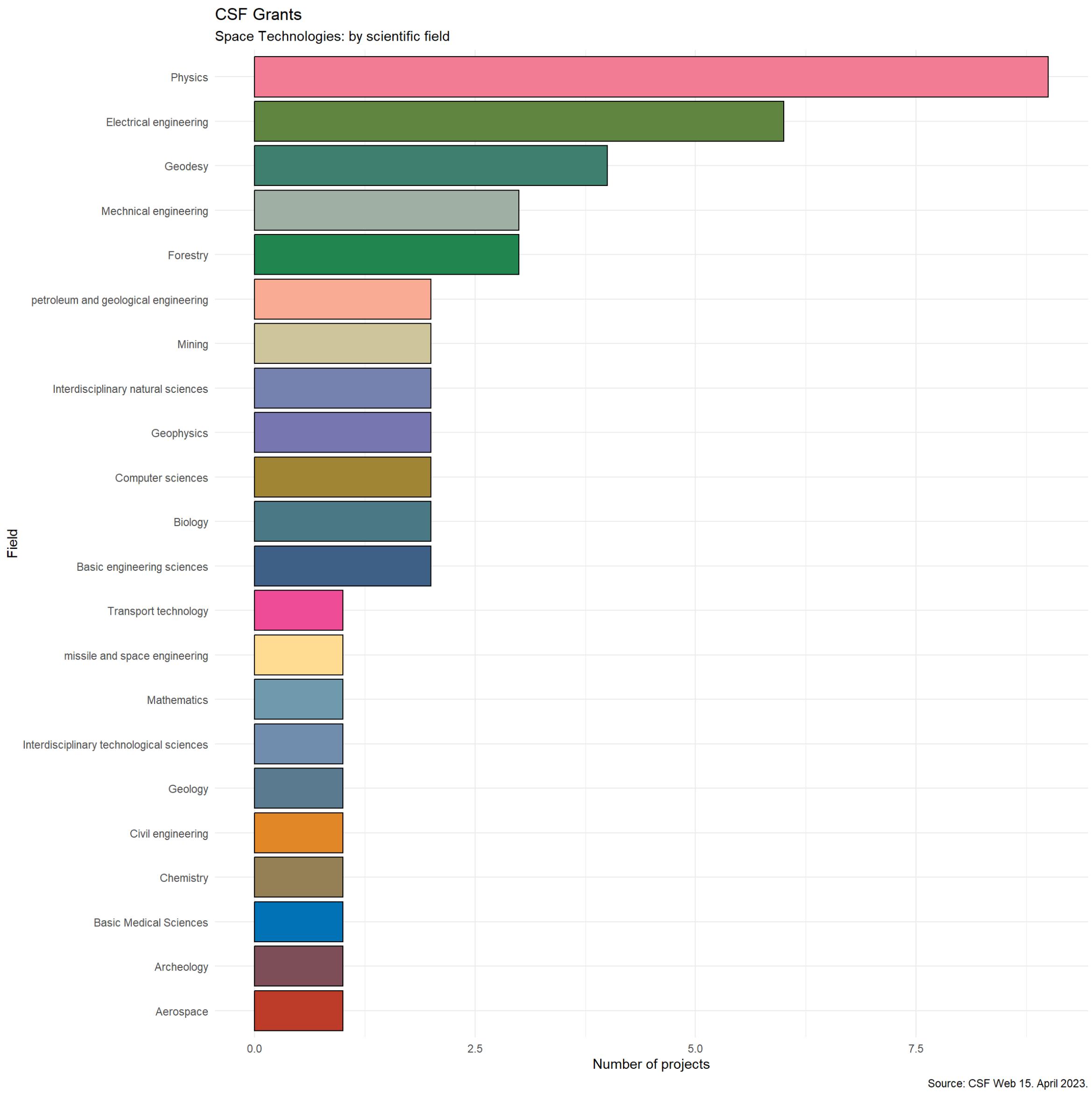


Figure 14 — Number of projects in the field of space technologies divided by scientific field. The chart relates to all CSF projects in the field of space technologies from 2013 until 2022. Some of the projects fall under two scientific fields and are listed under both.

Figure 15 shows the distribution of projects in the field of space technologies by scientific field. The technical and natural sciences are equally the most prevalent, which is the expected result.

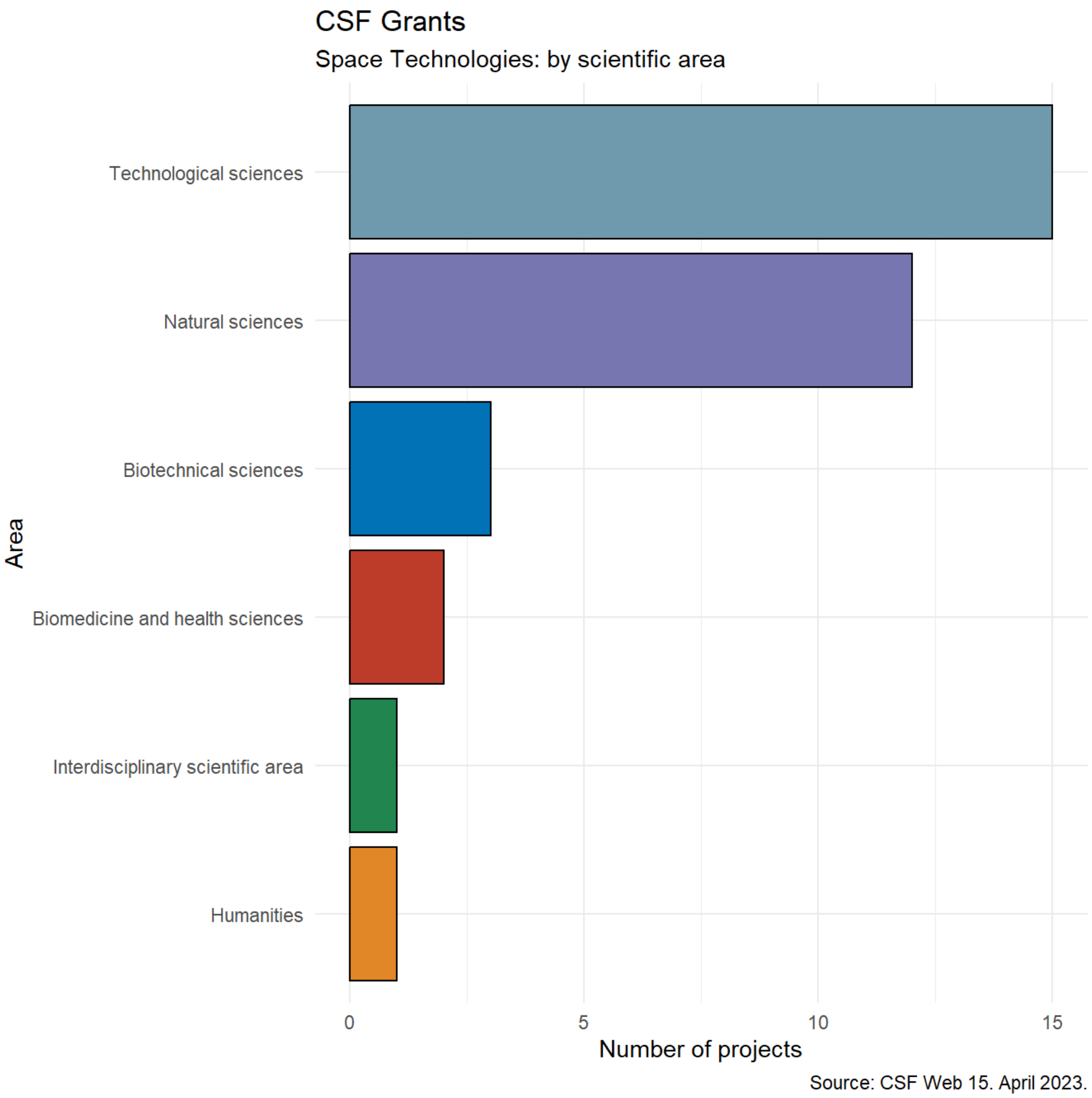


Figure 15 — Distribution of projects in the field of space technologies by scientific field.
The chart relates to all CSF projects in the field of space technologies from 2013 until 2022.

Figure 16 shows the distribution of projects by scientific field over the years.

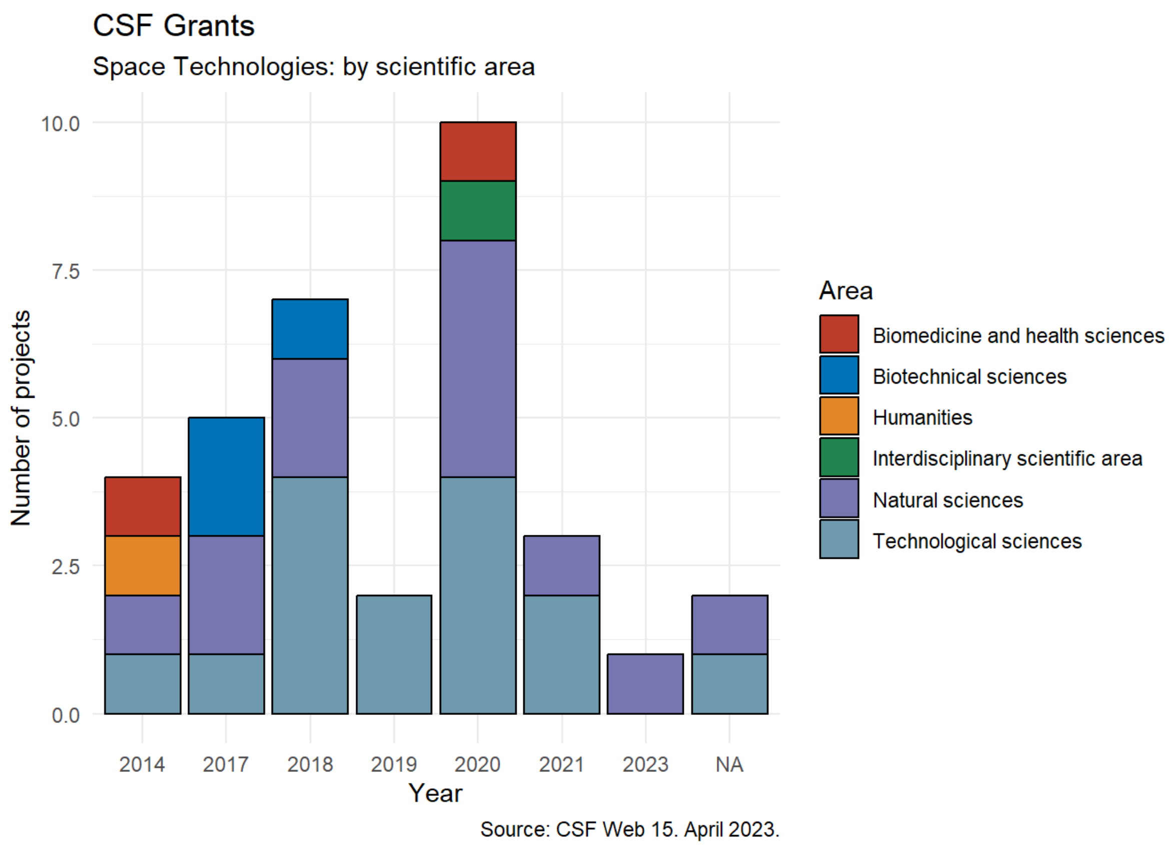


Figure 16 — Distribution of projects in the field of space technologies by scientific field over the years. Each project is listed only once in the year in which it was contracted. In the years not seen on the chart, there were no contracted projects related to space technologies. NA refers to those contracted CSF projects for which the available data did not indicate the starting date of the contract.

Finally, a very significant chart shows the distribution of CSF projects by institution (see Figure 17). In the field of space technologies, the projects were predominantly implemented at the Faculty of Geodesy of the University of Zagreb, then at the Faculty of Electrical Engineering and Computing and the Faculty of Science, both of the University of Zagreb, and lastly at the Forest Research Institute. Among the top ten public institutions working in space technologies, the same institutions are found as in other secondary data databases, indicating the consistency of the study. It is important to note that private institutions mostly did not participate in CSF projects unlike the EU funding instruments analysed in previous chapters, so they cannot be compared.

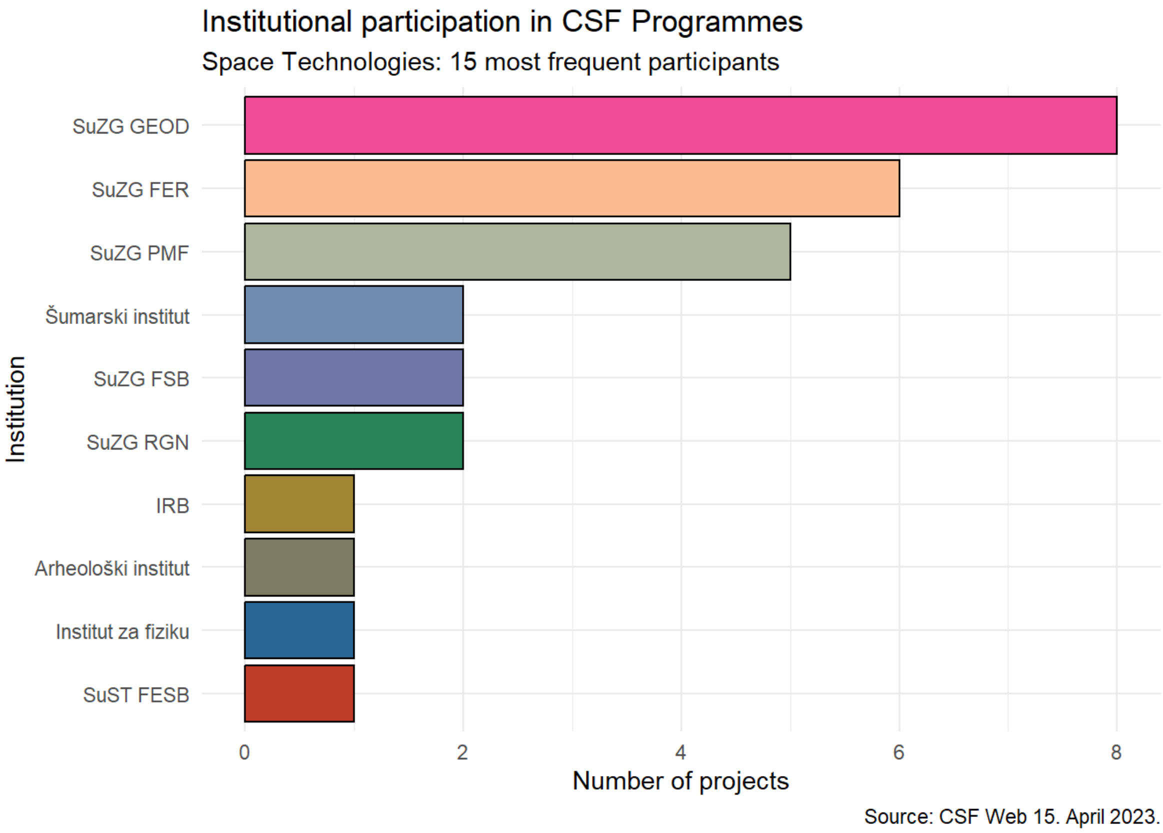


Figure 17 — Distribution of CSF projects by institution. The chart relates to all CSF projects in the field of space technologies from 2013 until 2022.

Ministry of Economy and Sustainable Development (HAMAG-BICRO)

In this part of the mapping, a series of calls for tenders is analysed that the Croatian Agency for SMEs, Innovation and Investments (HAMAG-BICRO) was in charge of implementing, which operates under the authority of the Ministry of Economy and Sustainable Development (see https://hamagbicro.hr/bespovratne-potpore/hamag-bicro-kao-korisnik-sredstava-tehnicke-pomoci/).

The information on the prevalence of space technologies in the programmes is obtained by detecting (by using the keywords) the projects concerning space technologies out of the total number of projects for a given programme. Figure 18 (top) shows the number of projects funded and the percentage of the total number of funded projects related to space technologies for HAMAG-BICRO programmes listed in Chapter 1.3. The figure clearly shows that projects related to space technologies are not very prevalent (approximately 1%–2% of projects) and that this number does not change significantly from programme to programme (in the sense that there is neither strong growth nor strong decline). The analysis of project applications, some of which were not funded, can be found below for those programmes for which data on applications was available.

HAMAG-BICRO programmes predominantly funded private sector legal entities. Public institutions were mainly present either as partners on some types of projects (RDI1 and RDI2) or as service providers in the innovation voucher programme.

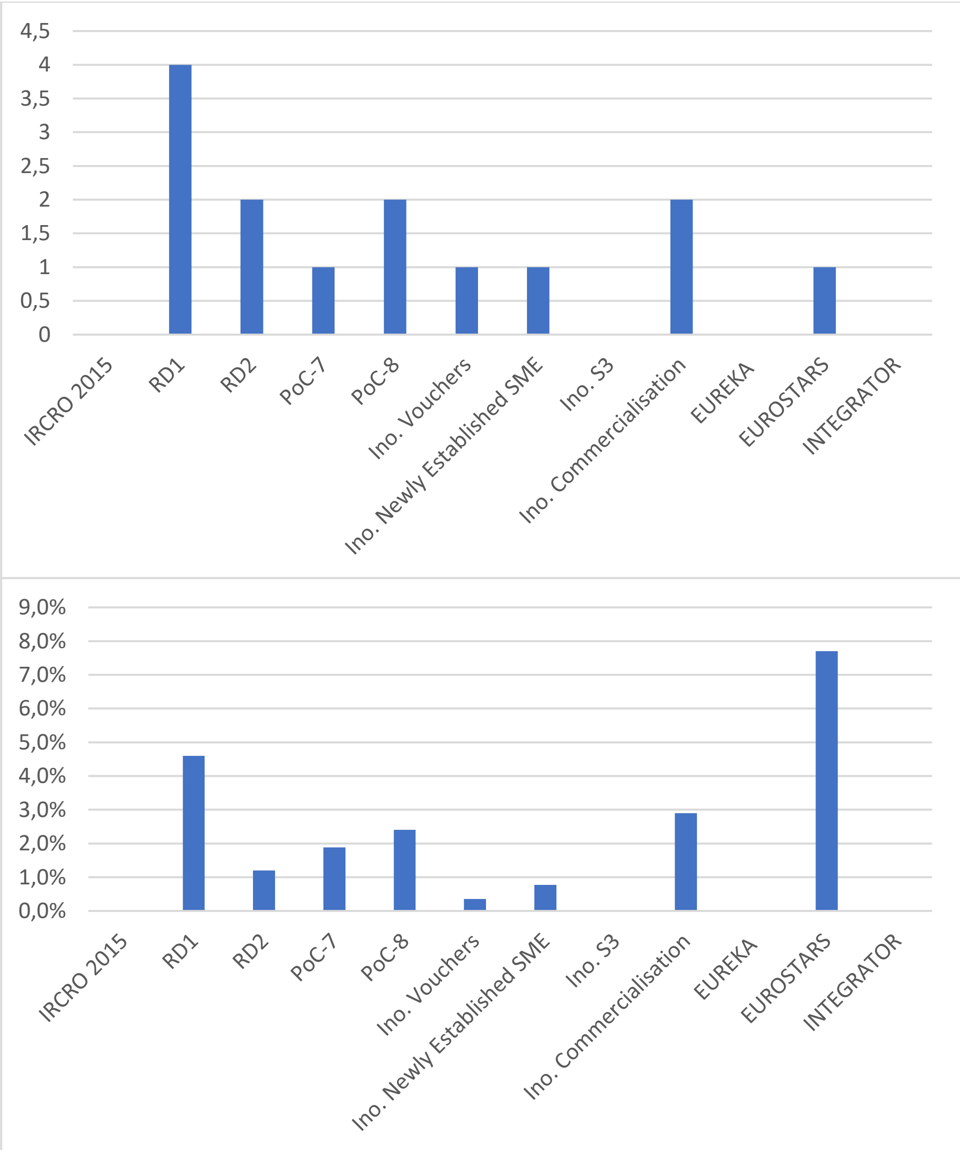


Figure 18 — Number of contracted HAMAG-BICRO projects in the field of space technologies by programme (top) and percentage of contracted HAMAG-BICRO projects in the field of space technologies by programme (bottom).

Below is a brief description of each programme and the number of projects related to space technologies detected under any given programme:

Knowledge-Based Companies Development — the RAZUM programme in 2015

The aim of the programme was to provide initial funding for newly established companies, i.e. to provide initial funding for the development of a new product or service in existing SMEs. From 2005 to 2013, 24 projects worth HRK 117,423,760 were financed through the RAZUM programme, while the RAZUM programme from 2015 funded seven projects worth HRK 24,662,693.00.

Under the call of the RAZUM programme from 2015, a total of 25 applications were received, one of which was related to the topic of space technologies, however, it was ultimately not funded.

Research and Development Programme — the IRCRO programme in 2015

The Research and Development Programme (IRCRO) has been implemented since 2008 and is still current. It encourages SMEs to cooperate with research institutions in launching their own R&D activities. The objectives of the programme are:

- encouraging SMEs to increase their R&D activities;
- nurturing and strengthening the link between the economic and scientific sectors;
- making better use of existing infrastructure in research institutions;
- helping SMEs to shorten the time frame for implementing R&D projects; and
- encouraging public scientific institutions to cooperate with the economic sector.

The analysis of the 2015 IRCRO call for tenders found one project application related to the field of space technologies out of a total of 60. This project application, which was not contracted, concerns the use of global positioning for the purpose of transport solutions without the development of space technologies. Out of the 60 applications, a total of 19 projects were contracted. In total, an amount of HRK 13,226,614.58 was contracted, i.e. an average of HRK 696,137.61 per project.

Proof of Concept programme — PoC

The PoC programme has been implemented since 2010 and supports innovations at the earliest stage of research in order to provide pre-commercial capital for technical and commercial proofing of the innovative concept. Between 2010 and 2020, eight PoC calls for tenders were implemented. In total, 359 projects were financed with HRK 102 million in grants, and the total value of the projects was HRK 154 million.

For the purpose of mapping the potential of space technologies, the titles and summaries of all the applications to the seventh and eighth PoC calls were analysed. The results were as follows.

Under the PoC-7 call, out of the total 135 project applications, two applications were in the field of space technologies. One project was contracted out of a total of 53 contracted projects. Under the PoC-8 call, out of a total of 154 project applications, four applications were in the field of space technologies. Two projects were contracted out of a total of 83 contracted projects. In terms of content, the project by Amphinicy d. o .o., Integrated System for Collecting and Storing Data of Distributed Megasatellite Networks (IDASS), stands out among the others. The other two contracted projects mainly used space technologies (GPS) without developing them.

Increasing New Product Development and Services Arising from Research and Development Activities programme — RDI1 and RDI2

The State Aid Programme for research and development (RDI) projects was launched in 2016 (RDI1 projects) and then again in 2019 (RDI2 projects). The call was open to applicants who were legal and natural persons as well as small, medium and large enterprises. The aim of the call was to increase private sector investment in R&D, to increase the number of entrepreneurs investing in R&D and to encourage the cooperation of entrepreneurs with research and knowledge dissemination organisations on R&D projects. In the first call, RDI1, the lowest contracted project amount was HRK 303,817.92 and the highest contracted project amount with Rimac Automobili was HRK 52,226,456.66. In the second call, RDI2, the propositions of the call were such that the total amount of available grants under RDI2 was HRK 1,561,448,500.28, and the maximum permitted total grant value per project proposal was HRK 30,000,000.00.

Within the framework of the RDI1 programme, by analysing the titles and summaries of the 87 contracted projects, three robotics projects and one project for the development of solar cells were detected. The technology developed and the know-how gained from these four projects can be applied in the field of space technologies.

Within the framework of the RDI2 programme, by analysing the titles and summaries of the 166 contracted projects, one project focused on the production of GPS navigation systems that can be classified under space technologies was detected. In addition, there was a project in robotics where the technology developed and knowledge gained can be applicable in the field of space technologies.

Innovation in S3 Areas programme

The Innovation in S3 Areas programme was launched in 2019, and the eligible applicants were micro, small and medium-sized enterprises. This programme encouraged entrepreneurs to commercialise product/service innovation in accordance with the identified thematic priority areas and inter-sector topics of the Smart Specialisation Strategy (S3). Innovative SMEs focused on the production and marketing of innovative products/services in their business activities and thus contributing to the competitiveness of the Croatian economy were supported. Among the 99 contracted projects, there were no projects in the field of space technologies.

Innovation Vouchers programme

The main objective of innovation vouchers is for research communities to transfer knowledge to micro, small and medium-sized enterprises (SMEs). By using vouchers, SMEs were able to obtain a service from the scientific community and thus transfer knowledge into their business. These were projects funded by lower amounts, specifically, the grant could not exceed HRK 75,000.00 per project proposal. Of the 279 vouchers awarded, one was in the field of space technologies.

Innovation at Newly Established SMEs programme — Phase II

This call encouraged the development of newly established SMEs by introducing innovations, i.e. the successful launch of products and services with the potential for growth and export that are new to the market. Companies with radical innovations and significant improvements in the commercialisation of products and services had the advantage. Of the 130 funded projects, one project was in the field of space technologies.

Innovation Commercialisation programme

The Ministry of Economy and Sustainable Development, under the National Recovery and Resilience Programme 2021 –2026, launched a call for project proposals related to the commercialisation of innovation that stimulates investments by micro, small and medium-sized enterprises (SMEs) aimed at producing advanced and innovative products and services of high added value. The call was published on 1 April 2022. The total amount of available funds was HRK 380,000,000.00, while the amounts of funding per project (i.e. the amount that can be awarded to any single applicant) were a minimum of HRK 760,000.00 and a maximum of HRK 5,320,000.00.

A total of 69 projects were contracted, two of which were in the field of robotics and are applicable to the development of space technologies.

EUREKA

EUREKA is a programme designed to launch research and development activities aimed at encouraging small, medium and large enterprises to cooperate with international partners.

Between 2015 and today, out of a total of 36 applications, one application was related to the field of space technologies, specifically Earth observation. In the period between 2015 and 2020, 12 projects were contracted but none in the field of space technologies.

EUROSTARS

EUROSTARS is a research and development programme created as a joint initiative of EUREKA and the European Commission. A minimum of two member states must participate in the consortium. The European Commission decided to contribute to SME development activities by participating with up to 25% of the total public co-funding under Horizon 2020 and Horizon Europe during their duration. The main partner in the consortium must be an SME engaged in R&D activities, while other project partners do not necessarily have to engage in R&D activities. There are no topic limitations, i.e. a project from any technological field may be submitted, provided that it has a social and civil purpose and includes the development of a new product, process or service.

Between 2015 and today, out of a total of 103 applications, 2 project applications were related to the field of space technologies. They covered Earth observation and downstream applications. From 2016 until today, 13 projects have been contracted, one of which is in the field of space technologies.

INTEGRATOR

This call encouraged the cooperation among small and medium-sized enterprises (SMEs) to establish supply relationships with integrator companies and become part of their value chain by creating new innovative products and services. The funding under this call was intended for co-financing innovation activities of a consortium of SMEs with the aim of establishing long-term supply relationships / value chains with other companies, the so-called integrators. No projects thematically related to the field of space technologies were found in the Integrator programme.

Secondary Data from Intellectual Property Databases — Patents

The analysis of secondary data related to intellectual property was done in several steps. In the first step, a broad set of classification codes from the IPC was selected (the International Patent Classification is a hierarchical scheme for the classification of patents, see https://www.wipo.int/classifications/ipc/en/). In order to detect patents and patent applications specifically in the field of space technologies, a wide set of codes was selected in the first step (see Table 2 at the end of this section).

The patents search was done for a period of 20 years (from 2002 to 2022) in order to gain a better insight into the development of technology where the applicants were legal and natural persons from the Republic of Croatia, and the source of the data was the Espacenet online database, which includes data from a large number of sources (the State Intellectual Property Office, available data on domestic applicants' applications in the EPO and WIPO and all other available national databases). After the list of patents and patent applications with their titles and application summaries was obtained, they were analysed individually and the patents belonging to space technologies were marked.

Within the field of space technologies, one patent application for a manned spacecraft was detected, as well as 30 items mainly related to the development of solar cells. The latter were not necessarily cells developed for use in space; however, because of the importance of the development of solar cells for space technologies, it is important to mention them. In conclusion, the number of patents in the field of space technologies from the Republic of Croatia is negligible. There is a possibility of growth if we compare the number of scientists who are active in the field with the broad possibilities of applying space technologies.

Table 2 — Selected patent classes relevant to the field of space technologies according to the IPC classification.

B64G	*COSMONAUTICS; VEHICLES OR EQUIPMENT THEREFOR*
G01S	*RADIO DIRECTION-FINDING; RADIO NAVIGATION; DETERMINING DISTANCE OR VELOCITY BY USE OF RADIO WAVES; LOCATING OR PRESENCE-DETECTING BY USE OF THE REFLECTION OR RERADIATION OF RADIO WAVES; ANALOGOUS ARRANGEMENTS USING OTHER WAVES*
G01J	*MEASUREMENT OF INTENSITY, VELOCITY, SPECTRAL CONTENT, POLARISATION, PHASE OR PULSE CHARACTERISTICS OF INFRARED, VISIBLE OR ULTRAVIOLET LIGHT; COLORIMETRY; RADIATION PYROMETRY*
G01K	*MEASURING TEMPERATURE; MEASURING QUANTITY OF HEAT; THERMALLY-SENSITIVE ELEMENTS NOT OTHERWISE PROVIDED FOR*

G01W	*Meteorology*
G01V	*GEOPHYSICS; GRAVITATIONAL MEASUREMENTS; DETECTING MASSES OR OBJECTS*
Y02A	*TECHNOLOGIES FOR ADAPTATION TO CLIMATE CHANGE*
Y02B	*CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO BUILDINGS, e.g. HOUSING, HOUSE APPLIANCES OR RELATED END-USER APPLICATIONS* [2018-05]
Y02D	*CLIMATE CHANGE MITIGATION TECHNOLOGIES IN INFORMATION AND COMMUNICATION TECHNOLOGIES [ICT], I.E. INFORMATION AND COMMUNICATION TECHNOLOGIES AIMING AT THE REDUCTION OF THEIR OWN ENERGY USE* [2020-08]
Y02E	*REDUCTION OF GREENHOUSE GAS [GHG] EMISSIONS, RELATED TO ENERGY GENERATION, TRANSMISSION OR DISTRIBUTION* [2018-05]
Y02P	*CLIMATE CHANGE MITIGATION TECHNOLOGIES IN THE PRODUCTION OR PROCESSING OF GOODS* [2015-11]
Y02T	*CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO TRANSPORTATION* [2017-05]
Y02W	*CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO WASTEWATER TREATMENT OR WASTE MANAGEMENT* [2015-05]

ESA Calls for Tenders in Croatia

In May 2020, the Implementing Arrangement on Technical and Professional Assistance entered into force. The purpose of the Implementing Arrangement was to determine the scope and modalities of the assistance to be provided by the ESA to the Republic of Croatia for the implementation of one or multiple calls for project proposals in the context of space-related activities. The Ministry of Science and Education, as part of the Implementing Arrangement, implemented a total of three national calls for project funding proposals from December 2020 to July 2022. Private and public institutions as well as the representatives of non-governmental organisations (NGOs) participated in the calls.

The areas covered by the call included:

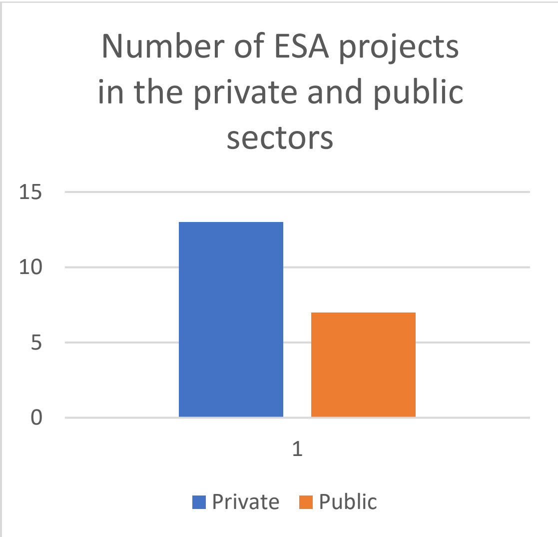
a) Earth observation;
b) space technology;
c) space situational awareness; and
d) space astronomy and astrophysics as well as the exploration of the solar system.

Total amount allocated to Croatian applicants under the first call: EUR 1,104,000 (11 approved projects).

Total amount allocated to Croatian applicants under the second call: EUR 968.276 (9 approved projects).

In all three rounds of the call, 64 project proposals were submitted and a total of 34 projects were approved for funding. Of the 34 approved project proposals, 16 were coordinated by the academic sector, while the remaining 18 project proposals were coordinated by the private sector. Croatian applicants have achieved the greatest success in the following areas: Earth Observation (16 approved projects), Space Technologies (11 projects), Space Science (4 approved projects) and Educational Activities (3 approved projects). **Since project summaries for only the first two rounds of the call were available during the writing of this report, this chapter presents an analysis of only those results (i.e. a total of 20 projects analysed).**

Figure 19 shows the number of projects and the total amount of funds awarded according to whether the applicants belonged to the private or the public sector. It is clear that about two-thirds of the applications were from the private sector. Such a distribution is expected as ESA calls focus primarily on the private sector.



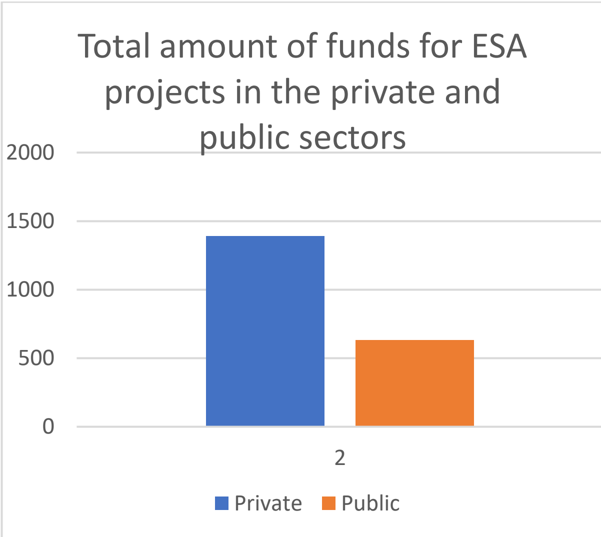


Figure 19 — Number of projects (left) and total amount of funds awarded (right) in thousands of EUR, classified according to whether the applicants belonged to the private or the public sector.

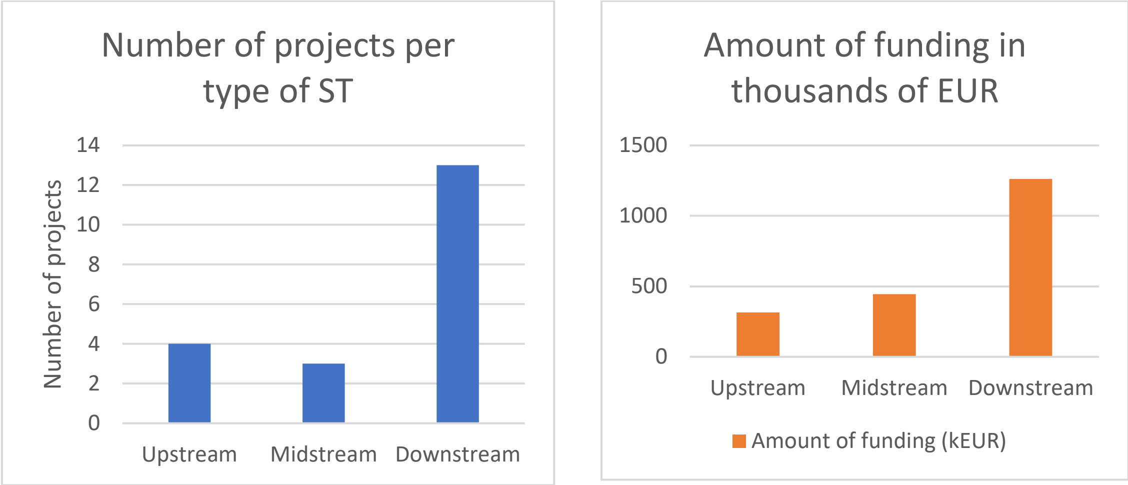


Figure 20 — Number of projects (left) and total amount of funds awarded (right) in thousands of EUR, classified according to whether they belonged to the downstream, midstream or upstream sector.

Figure 20 shows the number of projects and the total amount of funds awarded according to whether they belonged to the downstream, midstream or upstream sector. It is clear that most projects fall under downstream applications, both in terms of number and size. Looking at the more detailed structure of the projects presented in Tables 3 and 4, it can be seen that most (11 out of 20 projects) fall under Earth Observation, i.e. the downstream sector. Of the five projects from the upstream sector, the highest number was related to structures (this is the contribution of a strong individual applicant, the company INETEC d. o. o., which belongs to the upstream sector; the term strong individual applicant is used for an applicant who has successfully applied also to other calls for tenders analysed above), while for all the other sectors, we have one or no projects. One of the stronger applicants in the midstream sector that also appeared in other calls was Amphinicy d. o. o., while one of the stronger applicants from the downstream sector was Oikon d. o. o.

Table 3 — Project structure (number of projects and amount of funding) classified by different types of ST. A more detailed division than the one in Figure 20 is given here.

	Type of ST (more detailed breakdown)	Number of projects	Amount of funding (thousands of EUR)
1	Structures	2	248
2	Propulsion systems	1	66
3	Load	1	50
4	Power supply systems		
5	Mechanisms		
6	Space subsystem control		
7	On-board data systems	1	100
8	Communication systems		
9	Optoelectronics		
10	Earth stations and operations	1	192
11	Support systems	1	153
12	Earth observation	11	1115
13	GNSS		
14	Satellite communication		
15	Sustainability in space	1	47
16	Other	1	100
	Total	20	2072

Table 4 — Project structure (number of projects and amount of funding) classified by different markets for space technologies.

	ST market	Number of projects	Amount of funding (thousands of EUR)
1	Earth observation	11	1115
2	GNSS		
3	Satellite communication	1	153
4	Earth segment	2	292
5	Flight operations	1	66
6	Research missions	1	100
7	Security in space	1	47
8	Other	2	298
	Total	20	2072

3. Analysis of Primary Data Regarding the Research and Project Activities of Croatian Scientists and Entrepreneurs in Space Technologies Topics

The methodology used to collect and analyse the primary data for mapping the potential of Croatian scientists in the field of space technologies was designed in such a way that the results be complementary to the results of the processing of the secondary data in order to draw high-quality and accurate conclusions from all the data. The first step identified **44 public scientific institutions** (public higher education institutions and public scientific institutes) for which there was an indication that they had staff working with space technologies or using them in their work. This indication was obtained from the secondary data, taking into account the research focus areas of those institutions. After that, letters were sent to the addresses of these institutions and a list of their employees working with space technologies was requested from the rectors, deans, directors and heads of those institutions (to the best of their knowledge). The letter itself clarified and listed all that space technologies included in order to make identification precise.

From the administrations of the public institutions, a list of **66 scientists** working in the field of space technologies was obtained. **This number is interpreted as the lower limit of researchers working in this field.** Specifically, the administrations sent a list of research heads, i.e. prominent scientists, and not of doctoral students who worked in the field but completed their research and moved on to the private sector. The interpretation of the numbers from the secondary and primary data is given in the conclusion. A survey was sent to the addresses of the identified scientists and it was completed by **38 scientists or 58%** of the researchers. A description of the survey, the collected data and its analysis is given below in this chapter.

When asked *How many **years of work experience** do you have in the academic and research sector in research related to the topic of space technologies*, the median response of the scientists and the mean value coincided and were both **12 years**.

When asked *Assess the percentage of time you devoted on average MONTHLY to scientific research in the field of space technologies as a percentage (%)*, the **median reported was 20% and the mean value was 22%**.

In addition to the primary data obtained from public scientific institutions, the primary data from companies working in the field of space technologies was also collected. In the first step, **52 companies** were identified for which there were clear indications that they were working in space technologies. **These were primarily companies that applied for three rounds of the call by the European Space Agency**, companies that previously applied to EU and HAMAG-BICRO projects or companies that were found through the Adriatic Aerospace Association. A survey that passed the pilot testing was sent to the addresses of these companies. We obtained **15 completed surveys** from the companies analysed in this chapter.

Chapters 3.2.–3.5. relate to surveys conducted at public scientific institutions. Chapter 3.6. refers to surveys conducted at private companies.

3.1. On the Survey

The survey was set up so as to enable research into the following parameters:

(i) the specific field within the field of space technologies that the scientist or company deals with (the possibility of marking multiple fields was given);
(ii) the application of these space technologies, i.e. the markets targeted by these applications;
(iii) the project activity of the scientists, i.e. of the institution they work at (the number of projects and sources of funding for completed projects and ongoing projects, i.e. projects that were in the process of being reviewed were all analysed separately in order to obtain information on the dynamics of research development);
(iv) collaboration with other scientists and institutions or economic entities to obtain information on the networking of public institutions and companies;
(v) the activity of scientists and companies in the protection of intellectual property (e.g. patents, number of patents applied for and granted, trademarks, number of licences or licensing agreements, etc.);
(vi) portfolio of scientific research results (whether the main results are scientific papers or some kind of commercialisation of the results); and
(vii) information on the capital infrastructure being used (the survey examined what the infrastructure was, who owned it, where it was located and whether it had been included in the Šestar database).

The survey for companies was somewhat modified compared to the survey for public scientific institutions. In addition to the above parameters, the survey for companies also contained questions about:

(viii) own resources that companies invested in the development of space technologies;
(ix) the number of employees working in this field and any recruitment plans; and
(x) future investment plans (including potential new areas in which they plan to work).

The above parameters summarise the essence of the questions contained in the surveys. For this report to be complete, the surveys sent to the scientific institutions or companies themselves are included herein.

3.2. Main Directions of Research at Public Scientific Institutions

Space technologies can be roughly divided into three segments: (i) upstream, (ii) midstream and (iii) downstream technologies, and a more detailed description of these segments is given in Chapter 1.3., Mapping Methodology. The distribution of the activities of scientists (in other words, the distribution of the scientists according to their area of interest) in these three segments of space technologies is shown in Figure 21. Figure 22 shows the detailed distribution of scientists according to their field of research.

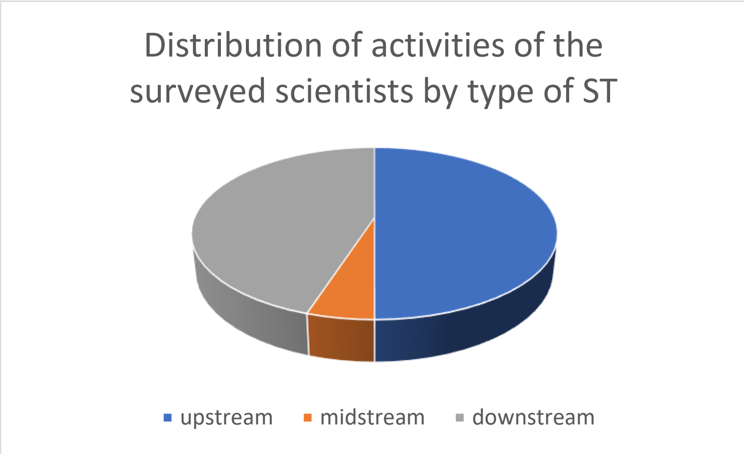
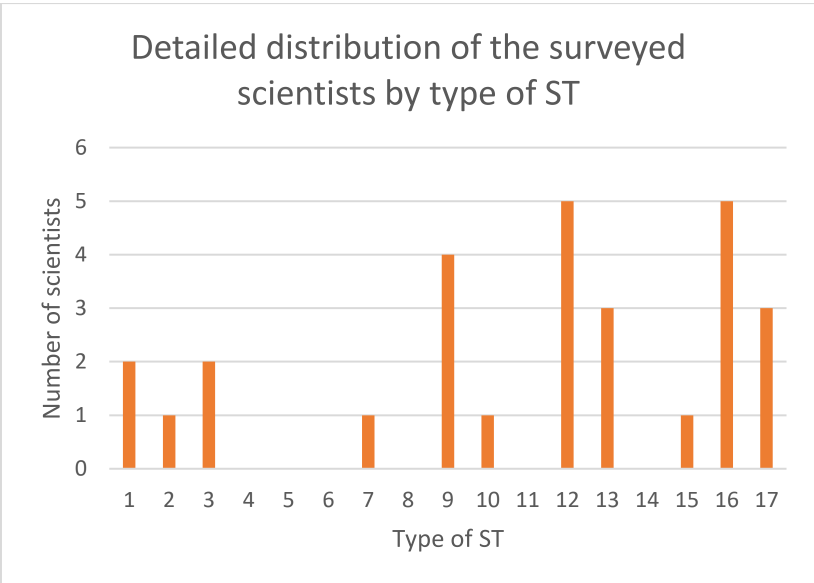


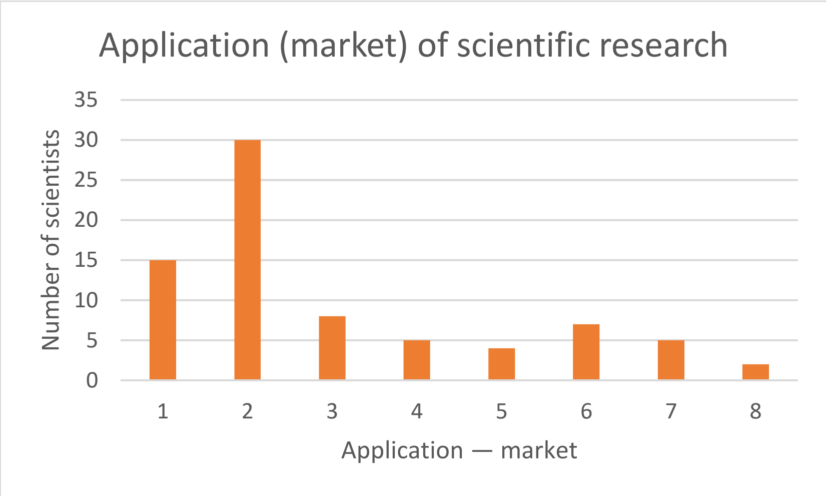
Figure 21 — The distribution of scientists, i.e. their areas of interest, according to the classification of space technologies into three groups: upstream, midstream and downstream.



1. Structures
2. Propulsion systems
3. Load (payload)
4. Power supply systems
5. Mechanisms
6. Space subsystem control
7. On-board data subsystems
8. Communication systems
9. Optoelectronics
10. Earth stations and operations
11. Support systems
12. Earth observation
13. GNSS
14. Satellite communication
15. Sustainability of space use and security in space, SSA (Space Situational Awareness)
16. Other
17. We do not develop space technologies but are implementing existing solutions.

Figure 22 — Detailed distribution of scientists, i.e. their areas of interest according to the type of space technologies. Each scientist was able to mark a maximum of two choices.

Figures 21 and 22 indicate that the number of scientists working with upstream and downstream technologies is roughly equal to the small domination of the downstream sector. Within the upstream sector, there are a higher number of researchers working with optoelectronics, while in the downstream sector, there are a high number of those working in Earth observation and GNSS. This distribution is also reflected in the distribution of scientists, i.e. the space technologies they are working with, by field of application of these technologies, as illustrated in Figure 23, where the surveyed scientists selected a maximum of two of the eight listed markets shown in Figure 23. The two most common responses were GNSS applications and Earth observation.



1. Earth observation
2. GNSS applications
3. Services relying on satellite communication
4. Earth segment
5. Flight operations
6. Research missions
7. Security in space — SSA
8. Other

Figure 23 — Distribution of scientists according to the application of their scientific research.

Although the survey was completed by only 38 scientists, since it was completed by scientists from 18 institutions, it can be assumed that this distribution would not have changed significantly even if it had been completed by all the scientists listed by their institutions.

3.3. Analysis of Project Activities and the Cooperation among Scientists, Institutions and Companies

In one part of the survey, the scope of the project activity of scientists was investigated. When asked *Were you involved in projects (completed, ongoing or proposed) in the field of space technologies, whether they be competitive scientific projects or collaborations with the business community*, 18 replied affirmatively (slightly less than 50%), while 20 claimed that they did not participate in such projects, as illustrated in Figure 24.

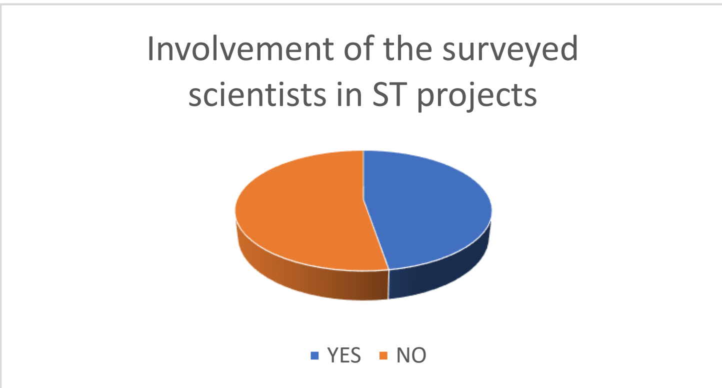


Figure 24 — Proportion of scientists who did (not) participate in projects in the field of space technologies.

Whether the scientist was a project leader or associate, and whether the institution at which they worked was the holder of such a project, was relevant for the assessment of potential. The answers to these questions in the survey were as follows. The number of projects in the field of ST where:

- the scientist was the principal researcher was 18
- the scientist was a research associate was 31
- the institution was the lead partner was 23.

The narrow speciality of the surveyed scientists was investigated by asking *Please provide keywords describing your scientific activity in the field of ST* and was found to be in the following research topics (we have grouped the answers and omitted repetitions):

- total error calculation for positions determined by GNSS systems, remote measurement using satellite navigation systems, application of remote systems in the field of border security;
- mapping of land cover and use, impact of open fires on the hydrological characteristics of catchments, application of thermal IR images in the mapping of coastal sources, water balance, survey (inventory) of forests, estimation of structural variables of forest stands;
- space forecast, processing of satellite data (in orbit around Earth and in the interplanetary space), geomagnetic storms, overcoming the effects of space time, ionospheric conditions and disturbances, multi-stage pathways and receiver deception on the quality of positioning by satellite systems (satellite navigation), statistical tests and statistical model development processes, spatial statistical learning and procedures for the development of predictive models, remote sensing, programmatically determined radio, nature-inspired procedures and algorithms for navigation;
- optoelectronics, laser technologies, quantum technologies (quantum communication) and photonics;
- the design, synthesis and characterisation of metal materials (alloy) with improved properties, alloys with improved properties, design of metal materials, synthesis of metal materials and characterisation of metal materials; and
- the influence of microgravity and hypomagnetic fields on biological processes.

These answers are in line with Figure 21 and it is clear in which downstream and upstream technologies our scientists work.

The following three tables show the distribution of completed, ongoing and proposed projects. These are projects involving the surveyed scientists.

Table 5 — Space technologies: number of COMPLETED competitive research projects (between 2016 and May 2023) under the programmes.

HORIZON 2020, Horizon Europe	2
Structural funds (RDI, SIIF, etc.)	2
UKF (Unity through Knowledge Fund)	1
PoC (Proof of Concept programme)	0
IRCRO, RAZUM, EUREKA, Eurostars	0

CSF (Croatian Science Foundation) programmes	10
Other scientific projects	8

Table 6 — Space technologies: number of ONGOING competitive research projects under the programmes.

HORIZON 2020, Horizon Europe	3
Structural funds (RDI, SIIF, etc.)	4
UKF (Unity Through Knowledge Fund)	0
PoC (Proof of Concept programme)	0
IRCRO, RAZUM, EUREKA, Eurostars	0
CSF (Croatian Science Foundation) programmes	1
Other scientific projects	9

Of the nine projects listed in Table 6, three are European Space Agency (ESA) projects and the rest are mainly bilateral projects.

Table 7 — Space technologies: number of PROPOSED competitive research projects.

HORIZON 2020, Horizon Europe	3
Structural funds (RDI, SIIF, etc.)	0
UKF (Unity Through Knowledge Fund)	0
PoC (Proof of Concept programme)	0
IRCRO, RAZUM, EUREKA, Eurostars	0
CSF (Croatian Science Foundation) programmes	0
Other scientific projects	0

Table 5 shows that our scientists prevalently used the funds from the CSF, Horizon 2020 and Horizon Europe and the structural funds. Project activity under the HAMAG-BICRO programme was very minor. This is partly understandable since these programmes are intended for companies. Table 7 shows that they are now focused on Horizon Europe projects, which is understandable as the publication of new calls for CSF projects has been reduced over the last few years.

The surveyed scientists carried out their projects and research in cooperation with scientific institutions in the Republic of Croatia and abroad and in cooperation with the business sector. Of the Croatian institutions, the questionnaires reported:

the Faculty of Geodesy, University of Zagreb, the Faculty of Science, University of Zagreb, the Faculty of Electrical Engineering and Computing, University of Zagreb, the Faculty of Transport and Traffic Sciences, University of Zagreb, the Faculty of Maritime Studies, University of Split, the Maritime Department of the University of Zadar, the Department of Physics, University of Rijeka, the Faculty of Engineering, University of Rijeka, the Faculty of Maritime Studies, University of Rijeka, the Faculty of Geotechnical Engineering, University of Zagreb, the Faculty of Agriculture, University of Zagreb, the Faculty of Forestry and Wood Technology, University of Zagreb, Virovitica University of Applied

Sciences, the Croatian Meteorological and Hydrological Service, Hrvatske vode, Zagreb Institute of Physics, the Croatian Geological Survey, KBC Zagreb and Hipersfera d. o. o.

The foreign collaborators were GFZ Potsdam, Germany, the Institute for Space Aeronomy (Belgium), the University of Graz (Austria), Observatorio del Roque de los Muchachos (Spain), GMV Aerospace and Defence S.A., University of Bristol, Austrian Academy of Sciences, the University of Ljubljana (Slovenia), Jožef Štefan Institute, MIT (USA), Max-Planck (Germany), Nankai University (PR China), Martin Luther University (Germany), the University of Liege (Belgium), the University of Innsbruck, Fraunhofer Institute (Germany), Beihang University (PR China), Gdynia Maritime University (Poland), the University of Ruse (Bulgaria), the National University of Science and Technology (NUST) (Pakistan), City University of New York (CUNY) (USA), China Research Institute of Radiowave propagation (PR China), the Faculty of Maritime Studies and Transport, the Finnish Geospatial Research Institute (Finland) and Renault Research (France).

The answers of the surveyed scientists when asked *Please indicate the number of projects in cooperation with the business sector (private companies, research centres, etc.) in which the business sector was the contracting authority in the field of ST* were as follows:

- number of companies from abroad 2
- number of companies from Croatia 6.

A total of 8 such projects were carried out.

The surveyed scientists evaluated the quality of collaboration in the field of ST so far with ratings from 1 (very poor) to 5 (very good). The ratings of the cooperation with stakeholders are as follows:

- cooperation with the research community 4.7
- cooperation with the business community 2.9
- cooperation with the government/public sector 2.8
- cooperation with the non-governmental sector 2.5.

It was evident that cooperation within the scientific community was evaluated as excellent, while cooperation between the scientific and business communities and among the scientific community and the state/public sector and non-governmental organisations, in this segment, has significant room for improvement.

In order to assess the motivation, i.e. the reasons, for cooperation from the perspective of Croatian scientists, they were asked to assess the importance of the following reasons for cooperation with partners (business sector and scientific institutions) on projects / scientific papers in the period from 2016 to 2022. The results are given in Table 8. The reasons for cooperation were mainly joint R&D projects and the transfer of knowledge between partners, while the less important reasons included the commercialisation of research and the licensing/registration of patents.

Table 8 — Assessment of the importance of the reasons for cooperation with partners (business sector and scientific institutions) on projects / scientific papers related to ST from 2016 to 2022. A scale ranging from 1 (not important) to 5 (very important) was used. The table shows the average rating for each question.

Joint R&D project	4.7
Transfer of knowledge between partners	4.4
Procurement of R&D services	3.0
Technological consultation / preparation of technical documentation	2.9
Testing/creating a new prototype	3.4
Commercialisation of research	2.6
Licensing/registration of patents	2.3
Intellectual property	3.1
Joint publication of research in journals	4.2
Some other reason	1.3

In order to understand what needs to be done to increase the number of collaborations and strengthen it, the reasons why this number is not higher were assessed using the questionnaires. The results are given in Table 9. The main reasons for the lack of cooperation were the lack of time (scientists are too busy with daily work) and the lack of resources (e.g. human or financial resources or research infrastructure).

Table 9 — Assessment of the importance of the reasons for there not being a higher number of collaborations. The responses were on a scale of 1 (not important) to 5 (very important). The table shows the average rating for each question.

We do not have enough information on the needs of the companies/institutions	3.4
We do not have enough incentives to work with companies/institutions	3.3
It is difficult to work with companies/institutions	2.5
The disclosure of business secrets in research is a concern	1.7
We don‘t have enough time because we’re too busy with daily work	3.6
We do not have enough resources (e.g. human or financial resources or research infrastructure)	3.9
There is no need for innovation and technology projects	1.9
Some other reason	1.5

3.4. Patents and Research Commercialisation

This part of the report analyses the primary data related to intellectual property and the commercialisation of research. When asked *Have you used some forms of intellectual property protection (patent, trademark, industrial design, copyright, etc.) for the results of your research in the period from 2016 to 2022*, 18% of the surveyed scientists replied YES and 82% replied NO (Figure 25).

The results show that one in five scientists use intellectual property protection, an unusually high number of patents when compared to those analysed from the secondary data.

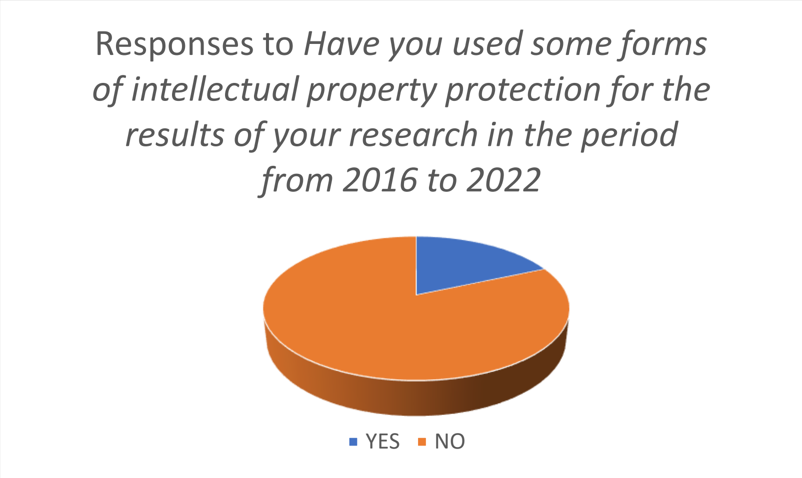


Figure 25 — Proportion of the use of intellectual property protection by the surveyed scientists.

An insight into the forms of intellectual property protection used is given in Table 10, from which it is evident that six of the surveyed scientists applied for one or more patents and one utility model, and did not use other forms of intellectual property protection. The number of national or international patents applied for and granted is given in Table 11. None of the scientists surveyed had any income from patent licenses. One scientist of the 38 surveyed started a spin-off company that is still active with one employee and a turnover of EUR 30,000 per year. However, no scientist has commercialised their research results in space technologies. The reasons for the lack of commercialisation were investigated by one survey question, and the answers are given in Table 13. No answer is significantly prevalent. Under *Other*, the scientists cited various reasons, but none stand out as a singular reason for the lack of commercialisation.

Table 10 — Number of different forms of intellectual property protection used by the surveyed scientists from 2016 to 2022.

Patent	6
Trademark	0
Industrial design	0
Copyright	0
Some other right (please specify): Utility model	1

Table 11 — Number of national or international patents applied for by the surveyed scientists and granted.

Number of national patents applied for	6
Number of national patents granted	2
Number of international patents applied for	8
Number of international patents granted	5

In order to determine the reason for the low number of patents, licensing and spin-off companies, we examined the reasons why scientists do not choose to protect intellectual property. The results are given in Table 12. It is clear that the main reason is that patent application is too expensive.

Table 12 — Reasons why the scientists did not use intellectual property protection. Replies to the question: If you have not used any form of intellectual property protection from 2016 to 2022, please provide a reason. Multiple answers may be selected.

The application process is too expensive.	33.3%
Maintaining protection is too expensive.	13.3%
The protection of intellectual property does not provide protection in our industry.	20.0%
Some other reason	33.3%

Table 13 — Answers of the surveyed scientists to the question regarding the lack of commercialisation. Question: If you have not commercialised the results of your research in the field of space technologies from 2016 to 2022, please indicate the reasons. Rate your answer on a scale from 1 (low importance) to 5 (high importance).

Lack of means for commercialisation	2.8
Lack of expertise and experience needed for commercialisation	2.8
Difficulties in finding a partner for commercialisation	3.0
Strong competition in the market	2.5
Insufficient market demand	2.3
Lack of support from the institution at which the scientist is employed	2.5
Commercialisation of research results was not planned/expected	2.8
Some other reason	1.6

The results achieved by scientists in the field of space technologies are predominantly scientific papers, followed by a manufactured or improved prototype of a product, as can be seen from Table 14. It is clear that the main motivation of scientists to work is the publication of scientific papers. This is related to the fact that their papers are important for their advancement, while the patenting and commercialisation of research are not crucial.

Table 14 — Answers of the surveyed scientists to the question regarding the results of research in the field of space technologies.

Manufactured or improved prototype of a product	19%
New service developed	6%
A new or significantly improved process	17%
Scientific papers	53%
Other	6%

3.5. Research Infrastructure

Of the total number of the scientists surveyed, 34% use capital research infrastructure (e.g. telescopes, satellites, supercomputers, data collection equipment, etc.) which, for the purpose of this study, was limited to equipment costing more than EUR 50,000. The scientists listed a total of 26 pieces of capital equipment falling under this definition (in fact, more than 26 because one response cited the Centre for Advanced Laser Techniques, which contains several pieces of equipment).

From the cited equipment, we highlight the Centre for Advanced Laser Techniques, the MAGIC Cherenkov telescope, spectrometers, the BURA supercomputer, optical and electron microscopes, equipment for testing the thermodynamic properties of materials, equipment for testing the mechanical properties of materials, LC-QToF-MS for complete water analysis, gas chromatographs for air analysis and data acquisition systems.

The percentage of equipment use is given in Table 15. The table is constructed on the basis of the question *What is the percentage of your use of this equipment for research purposes during the year*. It is obvious that the equipment is used significantly. **50% of the equipment was owned by the scientific institutions** that used it, and **50% was either rented or** used in other ways. Of the equipment owned by the institutions, **42% was included in the Šestar database, 34% of the equipment was not included,** and for the remaining part, the scientists who used it did not know the answer.

Table 15 — Percentage of use of capital equipment. Only 8% of the scientists used the equipment for research purposes during less than 25% of the year.

Percentage of equipment use:	Replies
< 25%	8%
25%–50%	15%
50%–75%	54%
75%–100%	23%

It can be concluded that equipment invested in research resources was used. Furthermore, since only 34% of the scientists used capital equipment, it is evident that there are human capacities to use a larger portion of research equipment.

3.6. Mapping the Potential of Croatian Companies in the Field of Space Technologies

It is known that some Croatian companies actively use space technologies in their work, i.e. that their products and/or services are related to space technologies. Some of them actively participate in the development of space technologies, while some of them only use, for example, satellite imagery to provide their services. The secondary data shows that Croatian companies are also participating in RDI funding programmes that touch on space technologies or are fully focused on them, such as European Space Agency (ESA) projects. **This part of the analytical report, based on the processed primary data (questionnaires), provides an insight into their aspirations and business activities, as well as an overview of answers to questions related to the type of space technologies they work with, target markets, cooperation with scientific institutions and other companies in the Republic of Croatia, project activities, intellectual property protection, plans for further development, which includes hiring new personnel in the field of space technologies, and placing products and services on new markets.**

Surveys were prepared to obtain precise information on the above topics, and the questionnaire itself is attached to this report. The surveys were sent to 52 companies, and 15 of them completed the questionnaire. The list of companies surveyed was compiled on the basis of the list of companies that applied to the three previous calls for tenders conducted by ESA along with the MZO, on the secondary data and the list of members of the Adriatic Aerospace Association.

The first part of the survey explored which type of space technologies the companies were involved with. In this part, the companies were to choose from seventeen possible answers, and it was allowed to mark more than one answer. These 17 responses can be grouped into three large sectors of space technologies (upstream, midstream and downstream), as explained in the mapping methodology. Figure 26 shows the distribution by the three sectors obtained from the survey, from which it is apparent that the surveyed companies were mostly focused on downstream technologies.

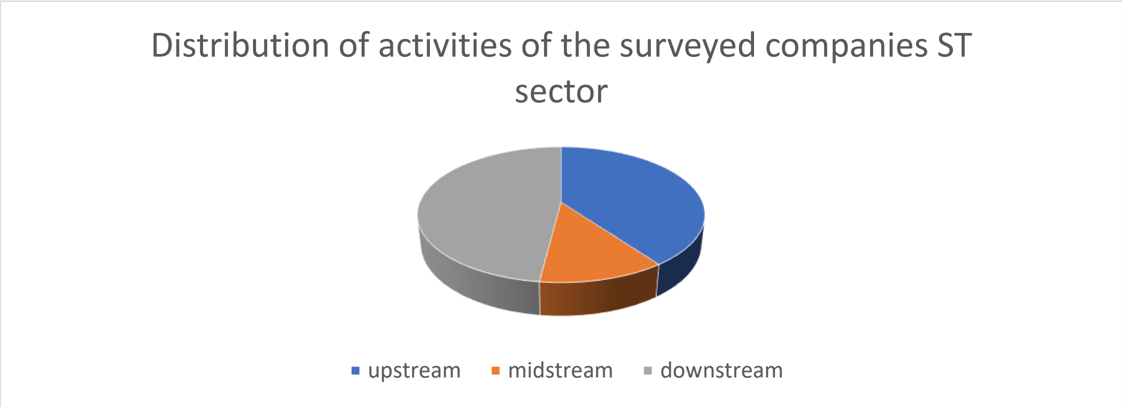
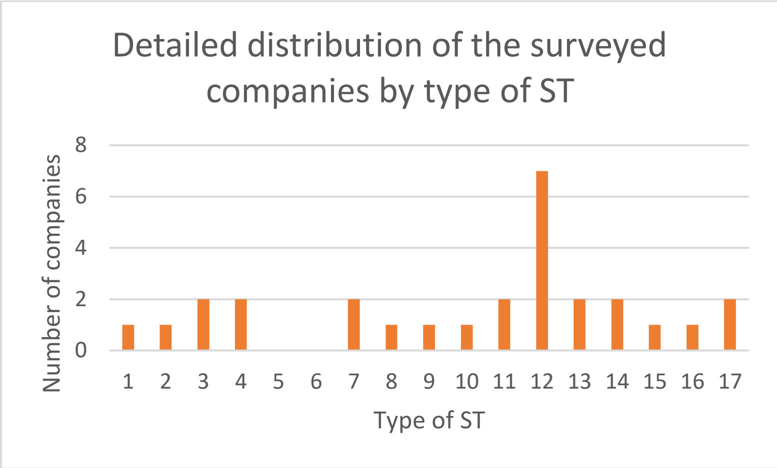


Figure 26 — Distribution of the surveyed companies by the three sectors of space technologies.

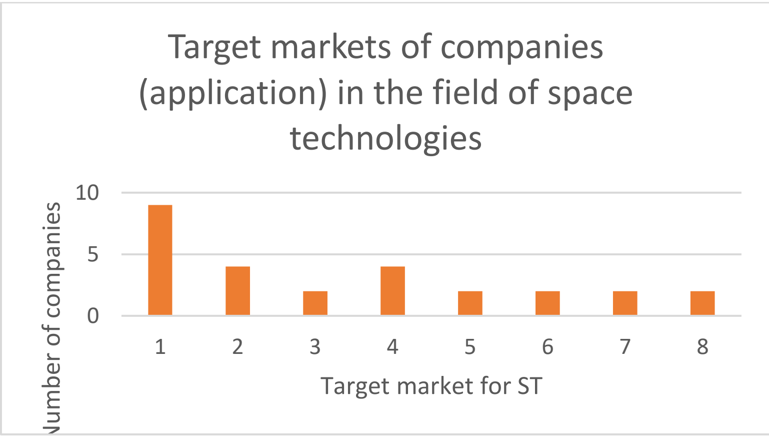
Figure 27 shows a more detailed distribution of companies' activities divided by type of ST. It is evident from the figure that there is no activity in the upstream and midstream sectors that significantly stands out from the others. Within downstream technologies, as could be expected to some extent, type 12 was the most represented. Earth observation



1. Structures
2. Propulsion systems
3. Load (payload)
4. Power supply systems
5. Mechanisms
6. Space subsystem control
7. On-board data subsystems
8. Communication systems
9. Optoelectronics
10. Earth stations and operations
11. Support systems
12. Earth observation
13. GNSS
14. Satellite communication
15. Sustainability of space use and security in space, SSA (Space Situational Awareness)
16. Other
17. We do not develop space technologies but are implementing existing solutions.

Figure 27 — Detailed distribution of the activities of the surveyed companies by type of space technologies. Types of ST 1–9 belong to upstream technologies, types 10–11 to midstream technologies and types 12–15 to downstream technologies (see the Methodology chapter for details).

An important piece of information is on which markets our companies place their products and services. The answer to this question is illustrated in Figure 28. The survey offered eight possible responses, i.e. eight markets, and each company was given the opportunity to select a maximum of three most important market sectors. The leading market was Earth observation, followed by the application of global navigation satellite systems (GNSS) and terrestrial operations.



1. Earth observation
2. GNSS applications
3. Services relying on satellite communication
4. Earth segment
5. Flight operations
6. Research missions
7. Security in space — SSA
8. Other

Figure 28 — Distribution of markets in the field of space technologies targeted by the surveyed companies.

The above three illustrations provide basic information on the characteristics of products and services, i.e. markets. The potential of these companies in a given field also depends on the number of employees working in space technologies (FTE — Full-Time Equivalent), the number of years of experience in this field, plans to recruit new personnel and the number of projects previously implemented. This information can be found in Table 16.

Table 16 — Summary of answers to survey questions intended for companies working in space technologies. All data refers exclusively to ST.

Total FTE	126.2
Average FTE per company	8.4
Average years of experience	6.8
Total number of projects implemented (2016 –2022)	60
Average number of projects implemented per company	4.0
Projects where the company was the coordinator	33
Average number of projects where the company was the coordinator	2.2
Average annual value (2016 –2022) of the R&D investment (in thousands of EUR)	72
Expected number of new employees in the next three years	58
Average number of new employees in the next three years per company	4.8
Planned development investments within the next three years (in thousands of EUR)	226

Table 17 shows the sources of financing for R&D projects, and own resources are prevalent at 53% followed by EU funds at around 32%. For planned projects, the data mostly follows the previous distribution with a small increase in the use of EU funds.

Table 17 — Sources of financing for previous and planned projects for the surveyed companies.

	Previous projects	Planned future projects
a) Own resources:	53%	40%
b) EU programmes and grants:	32%	44%
c) EU financial instruments (loans with low interest rates, guarantees on loans from commercial banks):	2%	1%
d) Commercial loan from a commercial bank:	0%	2%
e) Other sources (please specify):	13%	14%

The current data related to cooperation with scientific institutions is that 60% of companies **cooperate with scientific institutions in the Republic of Croatia** on problems related to the field of space technologies, while 80% **of companies plan to continue/commence such cooperation in the future**. The institutions mentioned in the questionnaires are the Faculty of Electrical Engineering and Computing, University of Zagreb, the Faculty of Science, University of Zagreb, the Faculty of Science, University of Split, the Faculty of Maritime Studies, University of Split, the Faculty of Agriculture, University of Zagreb, the Faculty of Geodesy, University of Zagreb, the Faculty of Transport and Traffic

Sciences, University of Zagreb, the Institute of Oceanography and Fisheries, Split, the Ruđer Bošković Institute, Algebra, Croatian Geological Survey and the Fraunhofer Institute for Industrial Mathematics. **With these institutions, the companies surveyed carried out 12 joint projects between 2016 and 2022.**

Collaborative relationships in other companies were as follows. **53% of the companies did not cooperate with other companies** on problems related to space technologies. The companies surveyed carried out 17 joint projects in the field of space technologies with other businesses in the period from 2016 to 2022, with as many as ten of these projects carried out by only one company, which should be taken into account when interpreting this statistical data.

Of the capital infrastructure, which, for the purposes of this survey, was defined as equipment worth over EUR 50,000, 33.3% of the companies used such infrastructure and 66.6% did not. Of the companies that used capital infrastructure, 100% owned their own infrastructure, while 90% used external capital infrastructure (see Figure 29). The percentage of equipment use for the development of space technologies was 73% (some companies used both their own and external infrastructure).

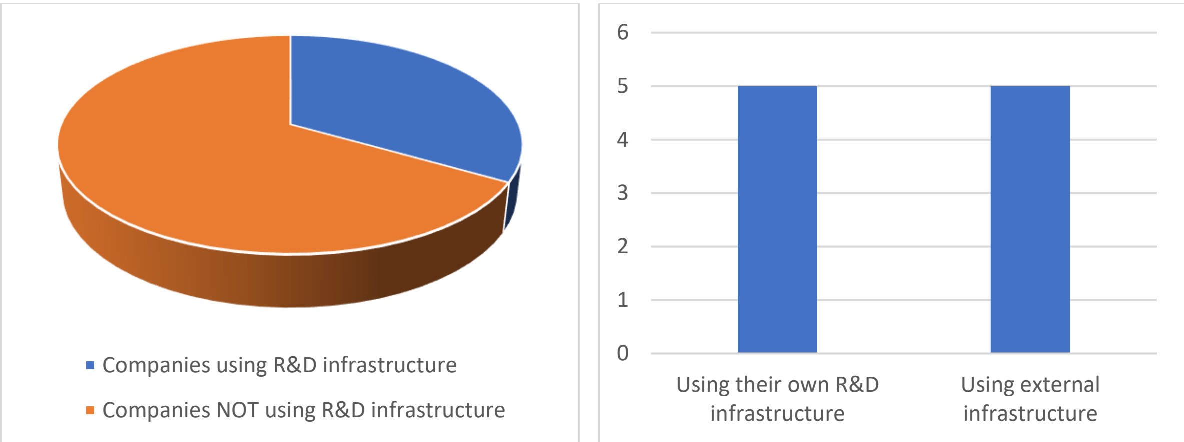
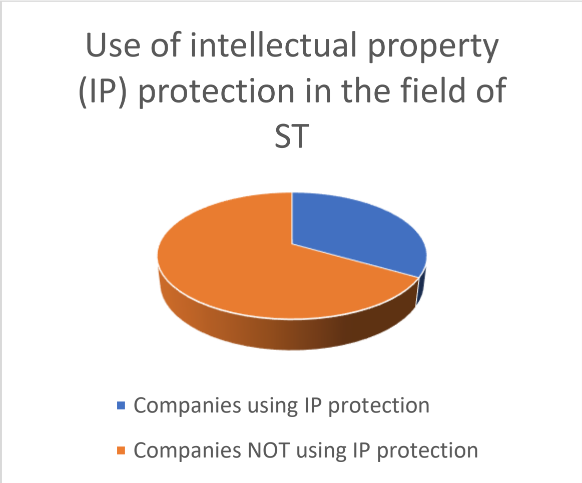


Figure 29 — Use of R&D infrastructure by the surveyed companies. The left chart shows the percentage of companies that use or do not use R&D infrastructure. The right chart shows the number of companies that use their own or external infrastructure. The right chart applies only to companies that use capital infrastructure.

The companies were not interested in sharing their capital infrastructure with other companies (only one surveyed company would allow the use of its equipment to other scientific institutions and only one to other companies). This own equipment mentioned in the survey included: large-diameter satellite antennas, development equipment at the company's premises, an internal data and processing centre at the company's premises, workstations, servers at the Zagreb Innovation Centre, 2 servers with video cards for training deep learning models, various camera and sensor models and drones, all of it largely located in the Republic of Croatia. The external equipment mentioned in the survey included: virtual machines with preconfigured algorithms and data, cloud solutions (Amazon or Microsoft), cloud services and data processing platforms (Orbify Ltd.) and laboratory equipment belonging to faculties (spectrometers, various sensors, etc.).

Of the companies surveyed, one third used intellectual property (IP) protection, and the structure was such that trademarks were what was predominantly protected (see Figure 30). No company surveyed had a patent, nor had it licensed IP protection elements in the field of space technologies.



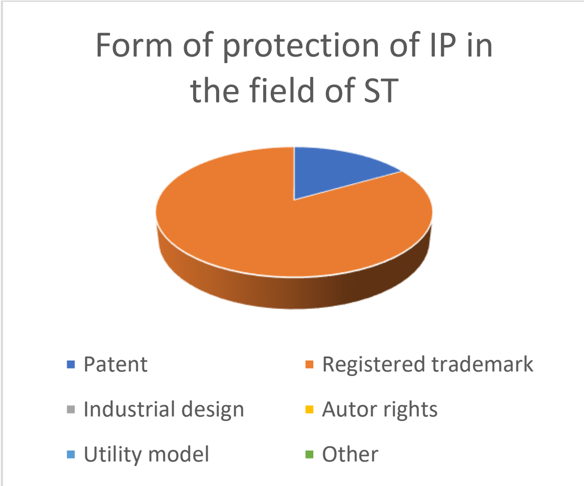


Figure 30 — Distribution of the use of intellectual property (IP) protection for surveyed companies (left) and distribution by type of IP in the field of ST (right).

It should be noted that 80% of the companies planned to expand their business to new markets, with 47% planning to use space technologies that they have not used before. Additionally, the companies that took the survey and are active in the field of space technologies currently employ 126 experts in that field, while also planning to hire another 58 experts in the next three years, which is an increase of 46%.

4. SWOT Analysis

Based on the primary and secondary data collected for the target area, a SWOT analysis was carried out, which shows the strengths (S), weaknesses (W), opportunities (O) and threats (T) within the target area of space technologies. SWOT analysis is a tool that helps analyse an organisation or technological field, identify internal strengths and weaknesses as well as external opportunities and threats, and help design a successful strategy for the future. A summary of the SWOT analysis is given in Table 18.

Table 18 — SWOT analysis. The table shows the strengths (S), weaknesses (W), opportunities (O) and threats (T) within the target area of space technologies in the Republic of Croatia. The list of strengths, weaknesses, opportunities and threats is based on the secondary and primary data.

STRENGTHS	WEAKNESSES
• A relatively small but professional community of researchers in the technical (electrical engineers or mechanical engineers), natural (physicists or meteorologists) and other fields (forestry or agronomy), which provides a good basis for further development of the area • Croatia’s existing and growing cooperation with the European Space Agency (ESA) and access to its programmes for co-financing R&D projects • The field of space technologies has seen moderate growth in Croatia, and there is an increasing interest and support through national strategic documents (NDS 2030, S3) and investors • Existing expertise at several scientific institutions cooperating with the economic sector, resulting in innovative projects • Applicability of solutions based on space technologies for a large number of sectors (security, cybersecurity, agriculture, tourism, environmental protection, etc.) • There is a community in the business sector of about 30 companies active in space technologies, largely in the downstream sector, but with several	• Lack of public perception of the importance of space technologies for the operation of a wide range of sectors • The dispersion of experts across the various institutions and the lack of a sufficient number of experts in the field • Lack of targeted higher education (graduate study) that prepares students to work in space technologies • Very low use of intellectual property protection to protect innovative solutions • The relative dependence on aid for the development and research of space technologies in the public sector, which makes this field vulnerable to changes in directions of financial incentives

prominent companies in other sectors of space technologies	
OPPORTUNITIES	**THREATS**
• A strengthening development of other sectors due to the strengthening of space technologies (in particular Earth observation) within them (agronomy, forestry, environmental protection and transport) Increased education and awareness of space technologies is needed to encourage the uptake of this technology in different sectors and by a wider range of users • Better management of disasters (e.g. fires or floods) and rare weather occurrences • The development and growth of the IT sector in the Republic of Croatia enables the use and commercialisation of space technologies, especially in the downstream sector (providing services of processing photographic/video data and communication solutions) • The development of start-up ecosystems with incubators and investors provides an opportunity to develop innovative solutions and entrepreneurship in space technologies • Potential contribution to digital transformation of different sectors in Croatia, which opens new opportunities for process optimisation and the creation of new values • Creating centres of excellence and competitiveness in the field of space technologies • Strengthening cooperation between the scientific and business sectors through support for R&D cooperation	• The lack of adequate funding for research and development of space technologies can limit the sector's potential growth • Croatia faces strong global competition, which requires continuous innovation and keeping up with the latest trends • Lack of highly educated new staff with competence that can be included in the operation of companies or research (in the public and private sectors) in the field of space technologies • Geopolitical tension can affect international cooperation, legal frameworks and the availability of resources, thereby limiting the growth of the field

5. Conclusions and Recommendations

5.1. Main Findings of the Mapping

One of the main objectives of this mapping was to estimate the number of researchers dealing with space technologies, i.e. those who have the capacity to implement research, development and other types of projects in that field. Based on the secondary data from the SCOPUS database, the upper **limit of this number was estimated at 294 researchers** in the public and private sectors. This figure was obtained by the following procedure: the first step filtered out all the authors who, within a period of eleven years (2012 –2022), published, in the SCOPUS database, scientific or other types of papers indexed by the said database and containing at least one of the keywords listed in Table 1 in their title, summary or list of keywords. In the second step, this list of authors was reduced to those with at least two keywords related to their name, i.e. 294 researchers. This figure of 294 individuals includes authors, i.e. researchers from public and private institutions. It is important to note that this figure also includes authors who may have published one paper in the period between 2012 and 2022, and then no longer worked with space technologies. Therefore, this is an estimate of the upper limit.

The lower limit of 66 researchers was obtained by contacting the administrations of **44 public scientific institution** which were concluded to have potential in this field, on the basis of the secondary data and taking into account the various professions (e.g. technical professions present in space technologies) present at these institutions. It should be noted that the figure of 66 researchers only includes researchers from public scientific institutions. **In conclusion, based on this mapping, it was estimated that there are between 66 and 294 space technology researchers in the Republic of Croatia.**

Based on the primary data, the conclusion is that the **aforementioned researchers from public institutions have worked in space technologies for an average of 12 years and that, on average, this field accounts for one-fifth of their working hours**. Just over half of the researchers were engaged in downstream technologies involving Earth observation for various applications, including forestry, agriculture, meteorology, the maritime sector and environmental conservation. As for upstream technologies, our scientists largely worked in optoelectronics, loads and structures. The secondary data showed that there were strong engineering groups in the field of robotics and automation that can focus part of their research on space technologies if needed, and that we have a group of researchers active in quantum technologies that are the focus of the EAGLE-1 project implemented by the ESA.

On the basis of secondary and primary data, public scientific institutions active in this area were filtered out: from the University of Zagreb, these were the Faculty of Geodesy, the Faculty of Electrical Engineering and Computing, the Faculty of Science, the Faculty of Transport and Traffic Sciences, the Faculty of Mechanical Engineering and Naval Architecture and the Faculty of Agriculture; from the University of Rijeka, these were the Faculty of Maritime Studies and the Faculty of Engineering; from the University of Split, these were the Faculty of Electrical Engineering, Mechanical Engineering and

Naval Architecture; of the various institutes, these were the Ruđer Bošković Institute, the Croatian Forest Research Institute, the Institute of Oceanography and Fisheries in Split, the Institute of Physics and the Croatian Meteorological and Hydrological Service.

The assessment of the quality/excellence of Croatian researchers working with space technologies is based on published papers, i.e. number of citations and based on implemented projects. Under the FP7 programme, a total of 14 projects that can be classified in the field of space technologies were contracted. In the Horizon 2020 programme, a total of 139 project applications in the field of space technologies were identified, of which 23 projects were contracted, 10 partners were from public institutions, while the partners of 14 of the contracted projects were entrepreneurs from Croatia. A total of five projects that can be classified in the field of space technologies were contracted under Horizon Europe (Horizon Europe data taken until April 2023 as the programme is still ongoing). In the first two calls for tenders by the European Space Agency in the Republic of Croatia, 20 projects with a total funding amount of over EUR 2 million were contracted. In the last two years (2021 and 2022), Croatian researchers published about 150 articles per year (according to the SCOPUS database) related to space technologies. The citation of scientific papers is relatively good, but there is room for improvement. From the above-mentioned estimated numbers of researchers and the number of projects contracted through EU, ESA and CSF calls, it is concluded that the level of quality or excellence of researchers is very good, but that there is room for improvement.

Based on the applications for the first two rounds of the European Space Agency's call, the secondary data, i.e. the applications for FP7, Horizon 2020, Horizon Europe calls and calls by the Ministry of Economy and Sustainable Development calls (the implementing body is the HAMAG-BICRO agency), the Croatian Science Foundation (CSF) as well as other bodies, it is estimated that, in the Republic of Croatia, we have about **30–40 companies who are active in the field of space technologies** or actively use them in their business. In the above-mentioned calls, the companies were very active (more active than scientific institutions in some programmes). Public scientific institutions were prevalently active only in CSF projects and in publishing scientific papers visible in the SCOPUS database. This is understandable because CSF projects were mostly not intended for companies and the sale of products and services is not necessarily linked to the publication of scientific papers. Among the most active companies, the ones standing out were Amphinicy d. o. o., Oikon d. o. o. (Institute of Applied Ecology), INETEC d. o. o. and Hipersfera d. o. o. Based on the primary data, it was clear that the dominant markets on which our companies were focused were related to downstream applications (Earth observation and GNSS). However, despite the numerical dominance of the downstream sector, the above-mentioned companies strong in space technologies were present in the upstream and midstream sectors also (INETEC d. o. o. and Amphinicy d. o. o.), so it is necessary to take this into account in the possible future adoption of a strategy for the development of space technologies.

With regard to the cooperation between the scientific and business communities on projects related to space technologies, based on the analysis of the secondary data received from HAMAG-BICRO, especially regarding RDI projects in which cooperation of this kind is encouraged, it would be superficial to conclude that the cooperation is infrequent. However, from the primary data, i.e. survey replies by scientists working at public scientific institutions, we see that eight projects were carried out where the contracting authority was from the business sector, which indicates a better level of cooperation after all, taking into account that 38 scientists completed the survey. The same conclusion followed from the surveys conducted at space technology companies: as many as 60% claimed that, between 2016 and 2022, they achieved some form of cooperation with public scientific institutions.

Lack of time (scientists from the public sector are too busy with daily work), lack of resources for collaboration (e.g. human or financial resources and research infrastructure) and the fact that scientists from the public sector do not have sufficient information about the needs of companies are cited as reasons for the lack of cooperation. It is also evident from the survey conducted at public scientific institutions that the protection of intellectual property and the commercialisation of research are not important motivators for scientists, which contributes to a lack of motivation for this kind of cooperation (this is somewhat understandable because scientific papers are valued more for advancement). Therefore, in order to strengthen the cooperation between the public and private sectors, it would be necessary to annul the circumstances set out above or minimise their impact.

5.2. Recommendations

Recommendation: continue and strengthen the cooperation with the European Space Agency. Let us reiterate the fact that the Government of the Republic of Croatia signed, on 23 March 2023 in Paris, the European Cooperating State Agreement between the Republic of Croatia and the European Space Agency, which allows the Republic of Croatia to participate in ESA programmes and activities. This agreement should be complemented by a Plan for European Cooperating States (the so-called PECS Charter). The continuation of the cooperation with the ESA until full membership is important for the Republic of Croatia from multiple aspects, such as the development of the business and technology sector that receives significant new opportunities through this cooperation, the development of a part of the academic sector that requires satellite technologies for adequate further development (meteorology, forestry, agriculture or transport) and the part of the academic sector that deals with fields close to or belonging to space technologies, where Croatia has significant potential. Continuing the cooperation with the ESA is also important from a security perspective, as it provides access to satellite data and satellite communication within the EU, i.e. independent from other major powers.

Recommendation: develop a strategy for the development of the space sector in the Republic of Croatia. The secondary and primary data shows that the business sector relies more on the use of downstream technologies. As far as the public sector is concerned, there is also a greater prevalence of downstream technologies, especially in terms of their use, however, there is potential in the upstream sector in some areas. When developing a strategy for the development of the space sector in the Republic of Croatia, it is necessary to enable adequate development and synergy of the above mentioned aspects of potential.

Recommendation: within the framework of developing a strategy for the development of the space sector in the Republic of Croatia, consider in particular the adoption of a decision on the establishment of a national space agency. Within the framework of developing a strategy for the development of the space sector in the Republic of Croatia, it is necessary to consider the existence of the need for the establishment of a body responsible for monitoring policies in the field of space and space technologies, to define the authority and responsibilities of that body, its method of governance and the benefits that the Republic of Croatia would have from such a body.

Recommendation: develop instruments to strengthen the cooperation between the private and public sectors in the field of space technologies. The cooperation between the business sector and the public scientific sector is not poor. In order to strengthen cooperation related to space technologies, it would be preferred to publish a targeted call for tenders financed by EU funds (analogue to RDI projects) that would stimulate that type of cooperation. In addition to this project, it is necessary to encourage the continuation of calls for supporting projects in cooperation with the ESA, and potentially to find within them a modality to stimulate joint business and public sector projects. There is particular potential for cooperation in using technology such as robotics, automation, artificial intelligence, optoelectronics, photonics and quantum technologies (quantum communication and optical clocks) for applications in space technologies. The above-mentioned project proposal would eliminate the lack of resources for cooperation.

One of the proposals is the organisation of half-day or one-day meets of researchers from the public and private sectors where companies would present their projects and needs to scientists from public institutions. Such meets would remove the obstacle of public scientists lacking sufficient information about the needs of companies.

Recommendation: strengthen instruments for encouraging the protection of intellectual property resulting from projects implemented in the public and private sectors. In order to strengthen the cooperation between the public and private sectors, it is important to eliminate the fact that the protection of intellectual property and the commercialisation of research are not important motivators of scientists in their work. It is necessary to ensure stable funding for the protection of intellectual property in public scientific institutions and to use adequate valuation to encourage scientists in the public sector to raise their level of competence in this field and to focus more attention on the management of intellectual property resulting from research. The patenting process, i.e. the hiring of patent agents and the payment of patent fees, requires significant financial resources if property is to be patented in more than one country (e.g. several EU, US or Asian countries). Better knowledge of the development of IP management strategies is necessary for cost optimisation and the potential commercialisation of solutions.

Recommendation: encourage the commercialisation of research. It is necessary to ensure, through public policy, that there is motivation for scientists to found start-ups or spin-offs. This includes raising awareness of the process of going from a scientific discovery at a public scientific institution and the protection of intellectual property to the establishment of start-ups or spin-offs, and ultimately to attracting investors or project funds for the initial operation of the company. Models for this type of process already exist in other countries, and those from the EU (Germany) and the US are of particular interest. This recommendation applies to other fields as well as to space technologies.

Recommendation: establish a graduate study programme in space technologies in the Republic of Croatia. One of the recommendations concerns the development of higher education in the field of space technologies. It is clear that experts whose research topics have an overlap with space technologies are spread across various public higher education institutions and institutes, i.e. that there is no faculty that has enough human resources to form a comprehensive graduate study programme in space technologies. However, at the University of Zagreb, there are enough human resources at several faculties that could in principle form a joint graduate study programme in the field of space technologies. It is recommended to hold a meeting with the administrations of the Faculty of Geodesy, the Faculty of Electrical Engineering and Computing, the Faculty of Science, the Faculty of Transport and Traffic Sciences, the Faculty of Mechanical Engineering and Naval Architecture and the Faculty of Agriculture and to launch an initiative for the establishment of such a programme, i.e. to define the undergraduate studies that would grant the right to enrol in the said programme. The starting point for the development of such a programme could be the FERSAT programme (https://www.fer.unizg.hr/zkist/en/FERSAT) implemented at SuZG FER.

Recommendation: encourage the strengthening of the quality and international recognition of Croatian researchers in the field of space technologies. From the data collected from the SCOPUS database, it was concluded that the level of quality or excellence of researchers is very good, but that there is room for improvement. Since space technologies are composed of a number of different scientific disciplines, the quality and international recognition of Croatian researchers in the field of space technologies can be encouraged by strengthening the synergy of research groups from different scientific fields and areas, which could result in internationally recognised publications. It is recommended to publish a targeted call for tenders financed by EU funds, which would have the active cooperation of at least three research groups from different institutions as a condition for application (a call somewhat analogous to an instrument of the European Research Council — Synergy Grants, appropriate for the Croatian research area). If the relevant implementing body wishes to restrict the call exclusively to space technologies, the budget should be adequately adjusted according to the number of research groups, and in this case, we recommend funding 1 or 2 of the best-ranked project applications.

Recommendation: construct and maintain databases for monitoring the development of space technologies as well as other areas, such as artificial intelligence, in the Republic of Croatia. In order to enable the future monitoring of the development of space technologies, as well as other thematic areas of interest to the Republic of Croatia, it is important to continue the development of databases that monitor the project activities of Croatian scientists and entrepreneurs (monitoring projects from relevant sources of funding such as Horizon Europe, EU funds, CSF or ESA) and research achievements by filtering them out periodically from the SCOPUS and/or WoS databases into the CROSBI or similar database, as well as the monitoring of acquisitions and use of infrastructure (further development of the database of the Croatian Research Information System, i.e. CroRIS, as well as of the Šestar database, which became part of the CroRIS database).

6. References and Appendices

6.1. List of Useful Links and References

- [Artemis] https://www.nasa.gov/artemisprogram
- [SpaceX — Dragon] https://www.spacex.com/vehicles/dragon/
- [NASA — Perseverance] https://mars.nasa.gov/mars2020/
- [ESA] https://www.esa.int/
- [ESA — 2023] Status Report on the Implementation of the Financial Framework Partnership Agreement (FFPA), including the EU-related part of the Navigation programme and the Copernicus Space Component, Paris, 13. 3. 2023
- [ESA — Galileo] https://www.esa.int/Applications/Navigation/Galileo
- [ESA — Copernicus] https://www.esa.int/Applications/Observing_the_Earth/Copernicus
- [EU — Copernicus] https://www.copernicus.eu/en
- [ESA — BepiColombo] https://www.esa.int/Science_Exploration/Space_Science/BepiColombo
- [JAXA — BepiColombo] https://global.jaxa.jp/projects/sas/bepi/
- [ESA — Euclid] https://www.esa.int/Science_Exploration/Space_Science/Euclid_overview
- [ESA — Space Rider] https://www.esa.int/Enabling_Support/Space_Transportation/Space_Rider
- [Cikota & Bogdan, 2018] S. Cikota and S. Bogdan, Representation of the Aerospace Sector in the Republic of Croatia, 2018.
- [Slovakia — 2020] Ministry of Education, Science, Research and Sport of the Slovak Republic, A Conceptual Framework of Space Activities in the Slovak Republic, 2020.
- [Czech Republic — 2020] The National Space Plan 2020–2025 of the Czech Republic.
- [Institute of Economics, 2022] https://mzo.gov.hr/UserDocsImages/dokumenti/EUfondovi/OPKK_2014-2020/ZTP/Analiticko-izvjesce-o-provedenom-znanstvenom-i-tehnologijskom-mapiranju-KK-01-1-1-03-0001.pdf
- [SCOPUS] https://www.scopus.com/search/form.uri?display=basic#basic
- Smart Specialisation Strategy https://mzo.gov.hr/vijesti/savjetovanje-o-prijedlogu-nacrta-strategije-pametne-specijalizacije-do-2029-s3/5203
- [ASJC] https://service.elsevier.com/app/answers/detail/a_id/15181/supporthub/scopus/
- [CSF — RP] https://hrzz.hr/programi/istrazivacki-programi/
- [CSF — YR] https://hrzz.hr/programi/razvoj-karijera/
- [CSF — International Cooperation] https://hrzz.hr/programi/medunarodna-suradnja%e2%80%8b/
- [HB — EUREKA] https://hamagbicro.hr/bespovratne-potpore/eureka/
- [HB — EUROSTARS] https://hamagbicro.hr/bespovratne-potpore/eurostars/
- [MINGOR — S3] https://hamagbicro.hr/otvoren-javni-poziv-inovacije-u-s3-podrucjima/
- [MINGOR — Voucher] https://hamagbicro.hr/javni-poziv-inovacijski-vauceri/

- [MINGOR — Innovation at Newly Established SMEs] https://hamagbicro.hr/javni-poziv-inovacije-novoosnovanih-msp-ova-ii-faza/
- [MINGOR — Innovation Commercialisation] https://hamagbicro.hr/objavljen-poziv-za-dostavu-projektnih-prijedloga-komercijalizacija-inovacija/
- [HB — IRCRO] https://hamagbicro.hr/bespovratne-potpore/programi-podrske-inovacijskom-procesu/ircro/
- [HB — RAZUM] https://hamagbicro.hr/bespovratne-potpore/programi-podrske-inovacijskom-procesu/razum/
- [MINGOR — RDI2] https://strukturnifondovi.hr/en/natjecaji/povecanje-razvoja-novih-proizvoda-i-usluga-koji-proizlaze-iz-aktivnosti-istrazivanja-i-razvoja-faza-ii/
- [Šestar] https://sestar.irb.hr/redirect.php
- [ERC] European Research Council — Synergy Grant https://erc.europa.eu/apply-grant/synergy-grant

6.2. Appendices

6.2.1. List of Tables

6.2.2. List of Figures

6.2.3. Glossary

Table 19 — Glossary

Term or acronym	Explanation
SCOPUS	SCOPUS is a comprehensive, expertly selected database of summaries and citations with enriched data and related scientific literature from various disciplines. It quickly finds relevant and authoritative research, identifies experts and provides access to reliable data, metrics and analytical tools.
Primary data	In order to collect the primary data that would give an insight into the two target areas, a survey questionnaire was created which included questions about basic information on the scientists, research and development projects, sources of funding, projects with the economic sector and other scientific institutions, infrastructure used, etc.
Secondary data	This data represents the data collected from available databases and secondary data sources of individual ministries, agencies and/or institutions related to different programmes in which researchers and engineers from the two target areas participate.
Research projects	For data related to contracted national competitive scientific projects, the projects taken into account were: — projects of the Croatian Science Foundation; — UKF projects; and — scientific projects from the European Structural and Investment Funds (excluding infrastructure projects). For data related to contracted international competitive scientific projects, the projects taken into account were:

	— projects of the EU Framework Programme for Research and Innovation (FP, H2020); — projects of the European Science Foundation (ESF); — projects of the Euroatom programme; — projects of the science foundations of EU countries; — projects of the National Institute of Health (NIH); — projects from Global Development Network donations; and — other projects for which public scientific institutes guarantee scientific significance and purpose (IPA as well as bilateral and multilateral projects are not included in this category).
Scientific organisations	The term *scientific organisation* refers to scientific institutes and higher education institutions which, in addition to higher education, carry out scientific activities, as well as scientific associations, state administration organisations and other public institutions carrying out scientific activities.

6.2.4. Survey Questionnaire

Survey Questionnaire for Researchers at Scientific Institutions

1. First and last name:
2. Name of scientific institution:
3. Email address of the researcher:
4. Telephone number of the contact person:
5. How many years of work experience do you have in the academic and research sector in research related to the topics Artificial Intelligence and Space Technologies? AI: ____, ST: ___
6. Please estimate the time you spent on average MONTHLY for scientific research in the fields of Artificial Intelligence (AI) and Space Technologies (ST) as a percentage (%): AI: ______% ST: ________%

7. Select the field where your R&D activities are most prevalent.

a) Artificial Intelligence (complete 7.1.) b) Space Technologies (complete 7.2.)

If you are active in both fields, please complete both parts of the questionnaire.

7.1. ARTIFICIAL INTELLIGENCE

Does your field of work relate to the development of AI methods and/or to the application of existing methods in one of the technological fields?

7.1.1. Development of artificial intelligence algorithms and methods (classification, regression, supervised, semi-supervised and unsupervised methods)

Please specify the algorithms and/or methods you are developing (e.g. neural networks, support vector methods, random forests and others), note that multiple answers are allowed:

A. k-nearest neighbours method;
B. support vector machines;
C. decision trees and random forests;
D. neural networks and deep neural networks; or
E. other, please specify: ______________________________
F. We do not develop artificial intelligence methods but use existing algorithms and methods.

7.1.2. Application of methods in the development of an innovative product or process to (choose up to three answers):

A. big data collection systems (image, voice or text);
B. planning and process management systems (e.g. traffic, manufacturing and industry processes, health capacity planning, urban planning or management of key national resources);
C. text recognition and processing systems (digitalisation and processing of archives);
D. image recognition and processing systems (archived or in real time, detection of objects in video surveillance or remote surveillance and reconnaissance from space, atmosphere and on Earth);
E. search systems (contextual search engines);
F. automotive systems (systems for autonomous or semi-autonomous driving, monitoring and movement of robots and machines);
G. expert systems to assist experts in medicine, natural sciences, transport, linguistics, psychology, philosophy, etc.;
H. game development systems (logical games such as chess or the development of virtual or augmented reality environments);
I. the development of legal or ethical standards and principles for the operation of artificial intelligence; or
J. other, please specify: ____

7.1.3. Please select the applications, i.e. target markets, of the technologies listed in question 7.1.2. Please cite up to three market sectors (if you are present in more than three, please specify the 3 most important ones):

1. automotive industry;
2. banking and financial services;
3. electrics and electronics;
4. ICT and telecommunications;
5. medicine and biomedicine, medical devices;

6. energy;
7. construction;
8. geospace and space;
9. food and drink;
10. innovation and design;
11. mechanical engineering and naval architecture;
12. quality and improvement of business;
13. marketing, advertising, customer relations;
14. measurement and metrology;
15. waste and recycling;
16. agriculture;
17. legal affairs;
18. risk and insurance;
19. mining and materials;
20. security (including cybersecurity) and defence;
21. transport and logistics;
22. information management;
23. environmental management and sustainability;
24. virtual reality;
25. data protection; or
26. entertainment.

7.2. SPACE TECHNOLOGIES

Does your field of work within space technologies relate to one of the following technological fields?

7.2.1. Please mark up to 3 of the 15 listed fields that are primary in your work (if you are active in more than 3 fields, mark the 3 primary areas of your work):

upstream technologies for the development, construction, launch and maintenance of space systems (1–9);

midstream technologies that serve to establish connections between space systems (e.g. functional satellites) and end users (10–11);

downstream technologies for the exploitation of space data as well as the development and production of equipment for end users and for (12–15);

1. structures (launch systems, satellite systems, tanks or thermal control);
2. propulsion systems (solid, liquid, hybrid or electric propulsion);
3. load (optical and infra-red (IR) instruments, radars, telecommunications and navigation, automation and robotics or adaptive systems);
4. power supply systems (solar panels, batteries or electricity distribution);
5. mechanisms (satellite mechanisms or launcher mechanisms);
6. space subsystem control (Attitude and Orbit Control (AOCS) sensors and actuators);

7. on-board data subsystems (on-board computers, microelectronics, machine learning and artificial intelligence for on-board data);
8. communication systems (RF technology, antennas or telemetry, tracking and command systems (TT&C));
9. optoelectronics (optical communication, photonics, quantum technology, detector technologies or laser technologies);
10. terrestrial stations and operations (terrestrial stations, missions or terminals);
11. support systems (terrestrial support equipment, data processing, data archiving or data systems);
12. Earth observation (EO);
13. GNSS (Global Navigation Satellite System), i.e. for global positioning and navigation;
14. satellite communication; or
15. sustainability of space use and security in space, SSA (Space Situational Awareness), which includes modelling and risk analysis, collision avoidance systems, laser satellite tracking and space debris and asteroids monitoring.
16. If you work with space technologies that are not listed in the 15 items above, specify your field of work here: ______________________________.
17. We do not develop space technologies but are implementing existing solutions.

7.2.2. Please select the applications, i.e. target markets, of the technologies listed in question 7.2.1. Please cite up to three market sectors (if you are present in more than three, please specify the 3 most important ones):

1. Earth observation with applications in meteorology and climate observation, climate change monitoring, sea and water observation, forests and agriculture observation, etc., the Copernicus programme, led by the European Commission and the ESA, etc.;
2. GNSS applications, including applications in air transport, maritime transport, vehicle control, time measurement and synchronisation as well as search and rescue applications, or general applications in the industry sector using global positioning, Galileo or European GNSS, etc.;
3. services relying on satellite communications (SatCom services), broadband services, broadcasting services, telemedicine, secure communication, etc.;
4. terrestrial context — Earth stations, telemetry, monitoring, management and control;
5. flight operations — launch centres or launch vehicles;
6. research missions — life science, microgravity and the International Space Station (ISS); or
7. security in space — SSA, the application of collision and space debris avoidance technology or space climate monitoring.
8. If you apply space technologies in a market sector not listed in the 7 items above, specify that sector here: ______________________________.

II. Main Areas of Scientific Activity

2.1. Please specify the keywords that describe your scientific activity in the fields of artificial intelligence and/or space technologies.

Artificial intelligence: ____

Space technologies: ____

III. Competitive Research Projects

3.1. Have you been involved in competitive research projects (completed, ongoing or proposed) in the fields of artificial intelligence and/or space technologies, be it competitive scientific projects or collaborations with the business community?

Artificial intelligence: a) YES b) NO

Space technologies: a) YES b) NO

3.2. If yes, please indicate the number of competitive research projects in artificial intelligence that you have worked on as:

a) Project leader: ______
b) Project associate _____
c) In how many projects listed under a) and b) did your institution participate as the lead partner /coordinator? ____

3.3. If yes, please specify the number of competitive research projects in space technologies you have worked on as:

a) Project leader: ______
b) Project associate _____
c) In how many projects listed under e) and f) did your institution participate as the lead partner /coordinator? ____

3.4. The completed and ongoing competitive research projects (in the period from 2016 until today) in which you participated or currently participate in the field of artificial intelligence / space technologies are funded from the following sources:

Programme	**Number of completed projects**	**Number of ongoing projects**
HORIZON 2020, Horizon Europe		
Structural funds (RDI, SIIF, etc.)		
UKF (Unity through Knowledge Fund)		
PoC (Proof of Concept programme)		
IRCRO, RAZUM, EUREKA, Eurostars		
CSF (Croatian Science Foundation) programmes		
Other scientific projects, please specify:_____________________________________		

3.5. Do you have any PROPOSED international competitive research projects (waiting for evaluation, verification and not in the implementation phase) related to the AI/ST thematic area?

a) Yes b) No

3.6. If yes, please indicate to which programme(s) you have submitted AI/ST competitive research projects.

Programme	**Number of projects submitted**
HORIZON 2020, Horizon Europe	
Structural funds (RDI, SIIF, etc.)	
UKF (Unity through Knowledge Fund)	
PoC (Proof of Concept programme)	
IRCRO, RAZUM, EUREKA, Eurostars	
CSF (Croatian Science Foundation) programmes	
Other scientific projects, please specify: _____________________________________	

3.7. Please indicate the number of projects in cooperation with the business sector (private companies, research centres, etc.) where the business sector was the contracting authority from the field of AI/ST.

AI: Number of projects: ____; of which the number of companies from Croatia was:____, of which the number of companies from abroad was:___

ST: Number of projects: ____; of which the number of companies from Croatia was:____, of which the number of companies from abroad was:___

3.8. In the listed projects, which areas are your speciality; where do you have the most knowledge and experience?
____
____

3.9. Please specify a few scientific institutions you have collaborated with as part of your AI/ST projects / scientific papers.

AI
Croatian institutions: __________________________
Institutions from abroad (name of institution/country):
____

ST
Croatian institutions: ____
Institutions from abroad (name of institution/country):
____

3.10. Please rate the importance of the listed reasons for cooperating with partners (business sector and scientific institutions) on competitive research projects / scientific papers related to AI and ST in the period from 2016 to 2022 on a scale of 1 (Not important) to 5 (Very important).

Joint R&D project	1	2	3	4	5
Transfer of knowledge between partners	1	2	3	4	5
Procurement of services for research and development (R&D)	1	2	3	4	5

Technological consultation / preparation of technical documentation	1	2	3	4	5
Testing/creating a new prototype	1	2	3	4	5
Commercialisation of research	1	2	3	4	5
Licensing/registration of patents	1	2	3	4	5
Intellectual property	1	2	3	4	5
Joint publishing of research in journals in the WoS or SCOPUS databases	1	2	3	4	5
Other, please specify:_______________	1	2	3	4	5

3.11. Please rate the quality of your cooperation in the field of AI/ST so far using ratings ranging from 1 (Very poor) to 5 (Very good).

Cooperation with the research community	1	2	3	4	5
Cooperation with the business community	1	2	3	4	5
Cooperation with the government/public sector	1	2	3	4	5
Cooperation with the non-governmental sector	1	2	3	4	5

3.12. Please rate the importance of reasons why there is not a higher rate of cooperation. Rate your answer on a scale from 1 (low importance) to 5 (high importance).

We do not have enough information on the needs of the companies/institutions	1	2	3	4	5
We do not have enough incentives to work with companies/institutions	1	2	3	4	5
It is difficult to work with companies/institutions	1	2	3	4	5
The disclosure of business secrets in research is a concern	1	2	3	4	5
We don‘t have enough time because we’re too busy with daily work	1	2	3	4	5

We do not have enough resources (e.g. human or financial resources or research infrastructure)	1	2	3	4	5
There is no need for innovation and technology projects	1	2	3	4	5
Other, please specify: ______________________________	1	2	3	4	5

IV. Intellectual Property and Commercial Potential

1. Have you used some forms of intellectual property protection (patent, trademark, industrial design, copyright, etc.) for the results of your research in the period from 2016 to 2022?

a) Yes b) No

2. If yes, which forms of intellectual property protection have you used to protect the results of your research between 2016 and 2022?

a) patent;
b) trademark;
c) industrial design;
d) copyright; or
e) some other right (please specify): _________

3. If you have applied for a patent, indicate how many patent applications you submitted from 2016 to 2022 in the
AI/ST thematic area.

a) National patents (Croatia):
Number of patents applied for:__________
Number of patents granted: __________

b) International patents (WIPO, EPO or the national patent offices of other countries):
Number of patents applied for:__________
Number of patents granted: __________

4. If you have not used any form of intellectual property protection from 2016 to 2022, please provide a reason. (Multiple answers may be selected.)

a) The application process is too expensive.

b) Maintaining protection is too expensive.
c) The protection of intellectual property does not provide protection in our industry.
d) Other, please specify: ____

5. Have you licensed (or had income from licensing) your patent between 2016 and 2022?

b) Yes b) No

6. Have you established spin-off and/or spin-out companies from 2016 to 2022 in the Artificial Intelligence and/or Space Technologies area?

a) Yes b) No

7. If you have established spin-off and/or spin-out companies from 2016 to 2022 in the AI/ST area, please answer the following questions.

a) How many such companies were established? _______________________
b) How many are still active? ________________________
c) How many employees do these companies have on average (data from the last relevant year):________________
d) How much revenue do these companies have on average (data from the last relevant year in EUR):________________

8. Please state the results of your research in the AI/ST thematic area.

a) Manufactured or improved prototype of a product;
b) new service developed;
c) a new or significantly improved process;
d) scientific papers; or
e) other, please specify: _____________________________

9. Have you commercialised the results of your competitive research projects between 2016 and 2022?

Note: commercialisation involves the use of knowledge from the scientific sector in the business sector to produce products and services for the market.

a) Yes b) No

10. If yes, please indicate the number of commercialisations in the period between 2016 and 2022.

______

11. If you have not commercialised the results of your research in the field of AI/ST in the period between 2016 and 2022, please indicate the reasons.

Lack of means for commercialisation	1	2	3	4	5
Lack of expertise and experience needed for commercialisation	1	2	3	4	5
Difficulties in finding a partner for commercialisation	1	2	3	4	5
Strong competition in the market	1	2	3	4	5
Insufficient market demand	1	2	3	4	5
Lack of support from the institution at which the scientist is employed	1	2	3	4	5
Commercialisation of research results was not planned/expected	1	2	3	4	5
Other, please specify: ______________________________	1	2	3	4	5

12. Please list the portfolio of professional services you offer on the market for R&D activities (contracted research, studies, testing or training) in the fields of AI/ST.

AI: _____________

ST: _______________

V. Research Infrastructure

In this section, please indicate whether you use R&D infrastructure worth more than EUR 50,000.

Artificial intelligence
5.1. Do you use capital research infrastructure and equipment (supercomputers, computer equipment, data collection equipment, etc.)?
a) YES b) NO

5.1.1. If yes, answer the following questions for up to three pieces of equipment that you most frequently use:

- Name of instrument/equipment _______________________________________

- What is the percentage of your use of this equipment for research purposes during the year?
a) < 25% b) 25%–50% c) 50%–75% d) 75%–100%
- Is the equipment included in the Šestar database?
a) YES b) NO c) I don't know
- Do you own this equipment?
a) YES b) NO
- If your answer to the previous question was NO, please indicate the owner of the equipment and where you use it. ________________________________ (name of institution/company, city and country)

- Name of instrument/equipment ______________________________________
What is the percentage of your use of this equipment for research purposes during the year?
a) < 25% b) 25%–50% c) 50%–75% d) 75%–100%
- Is the equipment included in the Šestar database?
a) YES b) NO c) I don't know
- Do you own this equipment?
a) YES b) NO
- If your answer to the previous question was NO, please indicate the owner of the equipment and where you use it. ________________________________ (name of institution/company, city and country)

- Name of instrument/equipment ______________________________________
- What is the percentage of your use of this equipment for research purposes during the year? a) < 25% b) 25%–50% c) 50%–75% d) 75%–100%
- Is the equipment included in the Šestar database?
a) YES b) NO c) I don't know
- Do you own this equipment?
a) YES b) NO
- If your answer to the previous question was NO, please indicate the owner of the equipment and where you use it. ________________________________ (name of institution/company, city and country)

Space technologies

5.2. Do you use capital research infrastructure and equipment (telescopes, satellites, supercomputers, data collection equipment, etc.)?
b) YES b) NO

5.2.1. If yes, answer the following questions for up to three pieces of equipment that you most frequently use:

- Name of instrument/equipment ______________________________________
- What is the percentage of your use of this equipment for research purposes during the year?
a) < 25% b) 25%–50% c) 50%–75% d) 75%–100%

- Is the equipment included in the Šestar database?

a) YES b) NO c) I don't know

- Do you own this equipment?

a) YES b) NO

- If your answer to the previous question was NO, please indicate the owner of the equipment and where you use it. ________________________________ (name of institution/company, city and country)

- Name of instrument/equipment ______________________________________
- What is the percentage of your use of this equipment for research purposes during the year?

a) < 25% b) 25%–50% c) 50%–75% d) 75%–100%

- Is the equipment included in the Šestar database?

a) YES b) NO c) I don't know

- Do you own this equipment?

a) YES b) NO

- If your answer to the previous question was NO, please indicate the owner of the equipment and where you use it. ________________________________ (name of institution/company, city and country)

- Name of instrument/equipment ______________________________________
- What is the percentage of your use of this equipment for research purposes during the year?

a) < 25% b) 25%–50% c) 50%–75% d) 75%–100%

- Is the equipment included in the Šestar database?

a) YES b) NO c) I don't know

- Do you own this equipment?

a) YES b) NO

- If your answer to the previous question was NO, please indicate the owner of the equipment and where you use it. ________________________________ (name of institution/company, city and country)

Please specify what you are missing in terms of research infrastructure to be able to generate new knowledge in research as well as innovation and ensure the transfer of new knowledge and technology in the
AI/ST thematic area to a greater extent.

____

Thank you for your participation!

Survey questionnaire for Companies

1. First and last name:
2. Company name:
3. Email address of the contact person:
4. Telephone number of the contact person:
5. Company size: a) micro b) small c) medium d) large
6. Total number of employees at the company (FTE): ______

7. Select the field where your R&D activities are most prevalent.

a) Artificial Intelligence (complete 7.1.) b) Space Technologies (complete 7.2.)

If you are active in both fields, please complete both parts of the questionnaire.

7.1. ARTIFICIAL INTELLIGENCE

In the questions below, please indicate whether your field of work relates to the development of artificial intelligence methods and/or to the application of existing methods in one of the technological fields.

7.1.1. Development of artificial intelligence algorithms and methods (classification, regression, supervised, semi-supervised and unsupervised methods)

Please specify the algorithms and/or methods you are developing (e.g. neural networks, support vector methods, random forests and others), note that multiple answers are allowed:

A. k-nearest neighbours method;
B. support vector machines;
C. decision trees and random forests;
D. neural networks and deep neural networks; or
E. other, please specify: ______________________________
F. We do not develop artificial intelligence methods but use existing algorithms and methods.

7.1.2. Application of methods in the development of an innovative product or process to (choose up to three answers):

A. big data collection systems (image, voice or text);
B. planning and process management systems (e.g. traffic, manufacturing and industry processes, health capacity planning, urban planning or management of key national resources);
C. text recognition and processing systems (digitalisation and processing of archives);
D. image recognition and processing systems (archived or in real time, detection of objects in video surveillance or remote surveillance and reconnaissance from space, atmosphere and on Earth);
E. search systems (contextual search engines);

F. automotive systems (systems for autonomous or semi-autonomous driving, monitoring and movement of robots and machines);
G. expert systems to assist experts in medicine, natural sciences, transport, linguistics, psychology, philosophy, etc.;
H. game development systems (logical games such as chess or the development of virtual or augmented reality environments);
I. the development of legal or ethical standards and principles for the operation of artificial intelligence; or
J. other, please specify: ____

7.1.3. Please select the relevant applications, i.e. target markets, according to the answers given in question 7.1.2. Please cite up to three market sectors (if you are present in more than three, please specify the 3 most important ones):

1. automotive industry;
2. banking and financial services;
3. electrics and electronics;
4. ICT and telecommunications;
5. medicine and biomedicine, medical devices;
6. energy;
7. construction;
8. geospace and space;
9. food and drink;
10. innovation and design;
11. mechanical engineering and naval architecture;
12. quality and improvement of business;
13. marketing, advertising, customer relations;
14. measurement and metrology;
15. waste and recycling;
16. agriculture;
17. legal affairs;
18. risk and insurance;
19. mining and materials;
20. security (including cybersecurity) and defence;
21. transport and logistics;
22. information management;
23. environmental management and sustainability;
24. virtual reality;
25. data protection; or
26. entertainment.

7.2. SPACE TECHNOLOGIES

Does your field of work within space technologies relate to one of the following technological fields?

7.2.1. Please mark up to 3 of the 15 listed fields that are primary in your work (if you are active in more than 3 fields, mark the 3 primary fields of your business activities):

upstream technologies for the development, construction, launch and maintenance of space systems (1–9);

midstream technologies that serve to establish connections between space systems (e.g. functional satellites) and end users (10–11);

downstream technologies for the exploitation of space data as well as the development and production of equipment for end users and for (12–15);

1. structures (launch systems, satellite systems, tanks or thermal control);
2. propulsion systems (solid, liquid, hybrid or electric propulsion);
3. load (optical and infra-red (IR) instruments, radars, telecommunications and navigation, automation and robotics or adaptive systems);
4. power supply systems (solar panels, batteries or electricity distribution);
5. mechanisms (satellite mechanisms or launcher mechanisms);
6. space subsystem control (Attitude and Orbit Control (AOCS) sensors and actuators);
7. on-board data subsystems (on-board computers, microelectronics, machine learning and artificial intelligence for on-board data);
8. communication systems (RF technology, antennas or telemetry, tracking and command systems (TT&C));
9. optoelectronics (optical communication, photonics, quantum technology, detector technologies or laser technologies);
10. terrestrial stations and operations (terrestrial stations, missions or terminals);
11. support systems (terrestrial support equipment, data processing, data archiving or data systems);
12. Earth observation (EO);
13. GNSS (Global Navigation Satellite System), i.e. for global positioning and navigation;
14. satellite communication; or
15. sustainability of space use and security in space, SSA (Space Situational Awareness), which includes modelling and risk analysis, collision avoidance systems, laser satellite tracking and space debris and asteroids monitoring.
16. If you work with space technologies that are not listed in the 15 items above, specify your field of work here: ______________________________.
17. We do not develop space technologies but are implementing existing solutions.

7.2.2. Please select the relevant applications, i.e. target markets, according to the answers given in question 7.2.1. Please cite up to three market sectors (if you are present in more than three, please specify the 3 most important ones):

1. Earth observation with applications in meteorology and climate observation, climate change monitoring, sea and water observation, forests and agriculture observation, etc., the Copernicus programme, led by the European Commission and the ESA, etc.;
2. GNSS applications, including applications in air transport, maritime transport, vehicle control, time measurement and synchronisation as well as search and rescue applications, or general applications in the industry sector using global positioning, Galileo or European GNSS, etc.;
3. services relying on satellite communications (SatCom services), broadband services, broadcasting services, telemedicine, secure communication, etc.;
4. terrestrial context — Earth stations, telemetry, monitoring, management and control;
5. flight operations — launch centres or launch vehicles;
6. research missions — life science, microgravity and the International Space Station (ISS); or
7. security in space — SSA, the application of collision and space debris avoidance technology or space climate monitoring.
8. If you apply space technologies in a market sector not listed in the 7 items above, specify that sector here: ______________________________.

The following questions allow answers for activities/work in both of the fields; if you are active in neither of the fields, please reply with 0.

8. Please indicate the number of employed engineers/researchers/experts working in the Artificial Intelligence and Space Technologies areas; please enter the number referencing FTE (Full-Time Equivalent). If your company does not work in one of the fields, please reply with 0.

8.1. Artificial intelligence: ___________ (FTE),

8.2. Space technologies: __________ (FTE),

9. How many years of work experience do you have (as a company or research group) in research related to the Artificial Intelligence and Space Technologies thematic areas? If your company has experience in both areas, please enter the number of years of work experience for both.

9.1. Artificial intelligence: ____ year(s).
9.2. Space technologies:____ year(s).

10. Number of R&D projects you have worked on under the thematic areas from 2016 until today and roles held on those projects (an R&D project implies planned research with the aim of acquiring new knowledge or developing new products/services/processes):

10.1.1. Artificial intelligence: A total of ___________ projects, of which projects where you participated as the coordinator of the whole project: ___________

10.2.1. Space technologies: A total of ___________ projects, of which projects where you participated as the coordinator of the whole project: ___________

11. Please provide an indicative average annual value (for the period between 2016 and 2022) of R&D investment in the thematic areas (human resources, equipment or other). We suggest rounding the amounts to the nearest thousand, in EUR. For example, if you invested EUR 100,025, round down to EUR 100,000. If your company does not work in one of the fields, please reply with 0.

Artificial intelligence: EUR ___________

Space technologies: EUR ___________

12. Sources of funding for research and development projects under the thematic areas If your company does not work in one of the fields, please reply with 0.

12.1. We funded R&D projects under the **Artificial Intelligence** thematic area from the following sources (express as percentages so that the sum of the percentages is 100%):

a) Own resources: ____%
b) EU programmes and grants: _____%
c) EU financial instruments (loans with low interest rates, guarantees on loans from commercial banks): _____%
d) Commercial loan from a commercial bank: ______%
e) Other sources (please specify): ______________________ (source), ____%

12.2. We funded R&D projects under the **Space Technologies** thematic area from the following sources (express as percentages so that the sum of the percentages is 100%):

a) Own resources: ____%
b) EU programmes and grants: _____%
c) EU financial instruments (loans with low interest rates, guarantees on loans from commercial banks): _____%
d) Commercial loan from a commercial bank: ______%
e) Other sources (please specify): __________________________ (source), ___%

13. Intellectual Property Rights Protection

13.1. Have you used some forms of intellectual property protection (patent, trademark, industrial design, copyright, etc.) for the results of your research in the period from 2016 to 2022?

a) YES b) NO (If NO, skip the questions about commercialisation and move on to question 14.)

13.2. Which forms of protection did you use for the results of your research from 2016 to 2022? For the selected replies, please also indicate the number of applications for protection if there were more than one.

<u>13.2.1. Artificial intelligence:</u>
a) Patent: _______
b) Trademark: __________
c) Industrial design: ___________
d) Copyright: _____________
e) Utility model: _____________
f) Some other form of protection (please specify): ______________, please specify the number:__________

<u>13.2.2. Space technologies:</u>
a) Patent: _______
b) Trademark: __________
c) Industrial design: __________________
d) Copyright: ____________
e) Utility model: _____________
f) Some other form of protection (please specify): ______________, please specify the number:__________

13.3. Have you licensed any of the elements of intellectual property protection?

13.3.1. Artificial intelligence: a) Yes, please specify the number of licenses _______ b) No

13.3.2. Space technologies: a) Yes, please specify the number of licenses _______ b) No

14. Cooperation with Scientific Institutions

Have you collaborated with scientific institutions under the two thematic areas between 2016 and 2022?

<u>14.1. Artificial intelligence:</u>
a) Yes
b) No

If yes, please indicate the number of projects collaborated on with scientific institutions during this period and list the institutions you have worked with under the thematic area.

14.1.1. Number of projects collaborated on with scientific institutions in the Artificial Intelligence area: ________

14.1.2. List of scientific institutions you have collaborated with in the Artificial Intelligence area:

____

14.2. Space technologies:

a) Yes

b) No

If yes, please indicate the number of projects collaborated on with scientific institutions during this period and list the institutions you have worked with under the thematic area.

14.2.1. Number of projects collaborated on with scientific institutions in the Space Technologies area: ________

14.2.2. List of scientific institutions you have collaborated with in the Space Technologies area: ____

15. Cooperation with Other Companies under the Thematic Areas

Have you collaborated with other companies under the two target thematic areas between 2016 and 2022?

15.1. Artificial intelligence:

a) Yes

b) No

If yes, please indicate the number of projects collaborated on with companies in the specified period.

15.1.1. Number of projects collaborated on with companies in the Artificial Intelligence area: ________

15.2. Space technologies:

a) Yes

b) No

If yes, please indicate the number of projects collaborated on with companies in the specified period.

15.2.1. Number of projects collaborated on with companies in the Space Technologies area: ________

16. Infrastructure

In this section, please indicate whether you use R&D infrastructure worth more than EUR 50,000.

16.1. Artificial intelligence

Do you use R&D infrastructure (supercomputers, computer equipment, data collection equipment, etc.) worth more than EUR 50,000?

a) YES b) NO

16.1.1. If yes, do you own your own R&D infrastructure or use infrastructure that is not owned by you (e.g. the infrastructure is owned by a scientific institution or by a commercial service provider)? Multiple answers may be selected.

a) We have our own R&D infrastructure for work on AI solutions. (Please specify the type and location.) _______________________________
b) We use external R&D infrastructure for work on AI solutions. (Please specify the type and location.) ______________ (name of institution/company, city and country)

16.1.2. Please indicate a percentage for the time of use of the said own equipment for developing solutions (the development of algorithms and methods as well as the application of methods) in the field of AI. _______%.

16.2. Space technologies

Do you use R&D infrastructure worth more than EUR 50,000?

a) YES b) NO

16.2.1. If yes, do you own your own R&D infrastructure or use infrastructure that is not owned by you (e.g. the infrastructure is owned by a scientific institution)? Multiple answers may be selected.

a) We have our own R&D infrastructure for work on solutions in the field of space technologies. (Please specify the type and location.) _________
b) We use external R&D infrastructure for work on solutions in the field of space technologies. (Please specify the type and location.) ______________ (name of institution/company, city and country)

16.2.3. Please indicate a percentage for the time of use of the said own equipment for developing solutions in the field of space technologies. _______%

16.3. If you own your own equipment and infrastructure, is there any possibility that you would rent it to other companies or scientific institutions, with the aim of achieving cooperation between scientific institutions and the private sector?

a) YES
b) YES — only to companies
c) YES — only to scientific institutions
d) NO

16.3.1. If you replied A, B or C, please specify the equipment you would be willing to rent to scientific institutions:
Artificial intelligence:
____

Space technologies:
____

17. Do you plan to recruit personnel to work in the Artificial Intelligence / Space Technologies areas in the next 3 years?

17.1. Artificial intelligence:
a) Yes (If yes, please specify the number of personnel you are planning to recruit.) __________
b) No

17.2. Space technologies:
a) Yes (If yes, please specify the number of personnel you are planning to recruit.) __________
b) No

18. How much do you plan to invest in development in the Artificial Intelligence / Space Technologies areas in the next 3 years? Round the amounts to the nearest thousand, in EUR. For example, if you invested EUR 100,050, round down to EUR 100,000. If you do not plan to invest, please reply with 0.

18.1. Artificial intelligence: EUR ____________

18.2. Space technologies: EUR ____________

19. Do you plan to collaborate with scientific institutions in the next 3 years?

19.1. Artificial intelligence:
a) Yes (If yes, please specify the institution with which you plan to collaborate.) ______________________
b) No

19.2. Space technologies:
a) Yes (If yes, please specify the institution with which you plan to collaborate.) ______________________
b) No

20. Do you plan to start working in new artificial intelligence / space technologies fields in the next 3 years (in which you have not worked so far)?

20.1. Artificial intelligence:
c) Yes (If yes, please specify these fields.) ______________________
d) No

20.2. Space technologies:
c) Yes (If yes, please specify these fields.) ______________________
d) No

21. How do you plan to fund future R&D activities?

21.1. Artificial intelligence:
a) Own resources: ____%
b) EU programmes and grants: _____%
c) EU financial instruments (loans with low interest rates, guarantees on loans from commercial banks): _____%
d) Commercial loan from a commercial bank: ______%
e) Other sources (please specify): ___________________________ (source), ___%

21.2. Space technologies:
a) Own resources: ____%
b) EU programmes and grants: _____%
c) EU financial instruments (loans with low interest rates, guarantees on loans from commercial banks): _____%
d) Commercial loan from a commercial bank: ______%
e) Other sources (please specify): ___________________________ (source), ___%

22. Do you plan to expand to new markets? If yes, please specify which ones.

22.1. Artificial intelligence:
a) Yes (If yes, please specify which ones.) ______________________
b) No

22.2. Space technologies:
a) Yes (If yes, please specify which ones.) ______________________
b) No

6.2.5. List of Acronyms and Abbreviated Names of Institutions Used in this Report

Table 20 — List of acronyms and abbreviated names of scientific institutions

Acronym or Abbreviated Name	Institution
Algebra	Algebra University College
DHMZ	Croatian Meteorological and Hydrological Service
Ericsson NT d. d.	Ericsson Nikola Tesla d. d.
HEP	Hrvatska elektroprivreda, Croatian national energy company
HKS	Catholic University of Croatia
HZJZ	Croatian Institute of Public Health
IFS	Institute of Physics
INANTRO	Institute for Anthropological Research
IOR Split	Institute of Oceanography and Fisheries
IRB	Ruđer Bošković Institute
Institute of Language	Institute of Croatian Language and Linguistics
KB Dubrava	Dubrava University Hospital
KB Fran Mihaljević	Fran Mihaljević University Hospital for Infectious Diseases
KB Merkur	Merkur University Hospital
KB Sveti Duh	Sveti Duh University Hospital
KBC Rijeka	Clinical Hospital Centre Rijeka
KBC SM	Sestre Milosrdnice University Hospital Centre
KBC Split	Split University Hospital
KBC Zagreb	University Hospital Centre Zagreb
MUP	Ministry of the Interior
NP Telaščica	Telaščica National Park
SSJEV	University North
SuDU	University of Dubrovnik
SuOS	Josip Juraj Strossmayer University of Osijek
SuOS EF	Josip Juraj Strossmayer University, Faculty of Economics
SuOS FERIT	Josip Juraj Strossmayer University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology
SuRI	University of Rijeka
SuRI BIOTEH	University of Rijeka, Department of Biotechnology
SuRI FF	University of Rijeka, Faculty of Humanities and Social Sciences
SuRI FIZ	University of Rijeka, Faculty of Physics
SuRI INF	University of Rijeka, Faculty of Informatics and Digital Technologies

SuRI MEF	University of Rijeka, Faculty of Medicine
SuRI POM	University of Rijeka, Faculty of Maritime Studies
SuRI RITEH	University of Rijeka, Faculty of Engineering
SuST	University of Split
SuST EF	University of Split, Faculty of Economics, Business and Tourism
SuST FESB	University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture
SuST GRAĐ	University of Split, Faculty of Civil Engineering
SuST KIN	University of Split, Faculty of Kinesiology
SuST MEF	University of Split, School of Medicine
SuST PMF	University of Split, Faculty of Science
SuST POM	University of Split, Faculty of Maritime Studies
SuZD	University of Zadar
SuZG	University of Zagreb
SuZG AGRO	University of Zagreb, Faculty of Agriculture
SuZG EF	University of Zagreb, Faculty of Economics and Business
SuZG FER	University of Zagreb, Faculty of Electrical Engineering and Computing
SuZG FF	University of Zagreb, Faculty of Humanities and Social Sciences
SuZG FKIT	University of Zagreb, Faculty of Chemical Engineering and Technology
SuZG FOI	University of Zagreb, Faculty of Organisation and Informatics
SuZG FPZ	University of Zagreb, Faculty of Transport and Traffic Sciences
SuZG FSB	University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture
SuZG GEO	University of Zagreb, Faculty of Geodesy
SuZG GRAĐ	University of Zagreb, Faculty of Civil Engineering
SuZG KIN	University of Zagreb, Faculty of Kinesiology
SuZG MEF	University of Zagreb, School of Medicine
SuZG PBF	University of Zagreb, Faculty of Food Technology and Biotechnology
SuZG PMF	University of Zagreb, Faculty of Science
SuZG PROMET	University of Zagreb, Faculty of Transport and Traffic Sciences
SuZG RGN	University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering
SuZG STOM	University of Zagreb, School of Dental Medicine
SuZG TTF	University of Zagreb, Faculty of Textile Technology
SuZG ŠUMFAK	University of Zagreb, Faculty of Forestry and Wood Technology
TVU Zagreb	Zagreb University of Applied Sciences
VU Krapina	Krapina University of Applied Sciences