NATIONAL SPACE PLAN
2020 – 2025

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Introduction

1.1 Preamble

The National Space Plan 2020-2025 (NSP) represents the strategy of the Czech Republic in further development of capacities and capabilities of its industry and academia in the space activities ensuring their competitiveness and maximising the return of the public investment in space activities and related areas, to increase well-being of the citizens of the Czech Republic. It also represents the policy of the Czech Republic to play a highly visible role within the international community in space and related areas and to increase influence of the Czech Republic on the European and global stage.

Space activities are all state, industrial and scientific activities that lead to the use of possibilities and opportunities which space opens to society. Space activities is a broad field that covers areas such as satellite navigation, satellite telecommunication, Earth observation, space transportation (including in particular launchers), space situational awareness, space exploration (both robotic and human spaceflight), space science (all fields of space astronomy, research in microgravity, effects of space environment) and applications and services connected with the use of obtained data.

The development of the Czech space sector is closely tied to European space policies and the strategies of the European Space Agency (ESA) and European Union (EU). The space sector and its activities are no longer only a concern of science. They represent a sector with an immense economic, social, strategic and security potential, which affects all domains of our lives and increase competitiveness and innovative and advanced technology status of the countries involved.

The NSP is implemented in accordance with international law and international commitments of the Czech Republic.

1.2 Premises

The Czech Republic has a long tradition in the utilization of space for scientific purposes which spans six decades. During the first decades, several scientific payloads and sensors were developed together with several small scientific satellites. These activities, taking into account the different economic and social context, were implemented mostly in scientific institutions with small industrial involvement and little economic consideration or sustainability.

In the last 30 years the Czech Republic has undertaken enormous political, economic and social changes. In the same period the economic development of the Czech Republic has been remarkable even if, at this stage, its competitiveness is still mainly based on the relatively low costs of its economy, although significant innovation initiatives are underway. Eurostat[1] statistics show a high level of high technological content of its exports (17.8 % in 2018), higher than e.g. Germany (15.1 %). On the other hand, the Czech Republic still has a relatively low number of patents, although significant progress has been achieved. The number of patent applications to the European Patent Office (EPO) has increased by 50 % since 2012 (to about 33.8 per million inhabitants in 2017), but is still around 7 times smaller than Denmark or Germany. The Czech Republic has also become a popular venue for innovation investments from abroad. According to OECD data,[2] almost 32 % of business enterprise expenditure on R&D in the Czech Republic was funded from abroad (up from 5.4 % in 2005).

In this framework, space-related activities have proven to be a unique tool to influence economic development by creating excellent examples and best-practices to be applied in other sectors of the economy. The need to retain and absorb the intellectual capital that is created in its academia and industry is an essential requirement to ensure the "return-on-investment" of the public investments.

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[1] EUROSTAT, Patent Applications to the European Patent Office (EPO) – Number of applications per million inhabitants, https://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=sdg_09_40&language=en and High-tech exports – Exports of high technology products as a share of total exports, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=htec_si_exp4&lang=en.

[2] OECD Science, Technology and Industry Scoreboard 2017, ISBN 978-92-64-26880-7, OECD 2017, p. 130.

Space is an area of economic activity with the highest potential for innovation[3] and represents a springboard to drive Czech economy's competitiveness. For EU, space is a political and economic challenge that can strengthen the position of the EU in the global economy.

Space is also an excellent example of an area where close international cooperation among states, big and small, is vital and works beyond possible political diversity.

ESA is the main tool for the Czech Republic to influence and develop space activities and participate in space projects. ESA is an agency whose mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the World. Because of this role, ESA has a strong R&D programme supporting space projects and because of the high risks and costs associated with space, it uses systematically a Technological Readiness Level (TRL) approach to evaluate the readiness of the technologies developed for possible use in space missions. For this reason, the R&D activities of ESA are very targeted and always involve industry at the higher levels of TRL that needs to bring these technologies to market. Academically led R&D is concentrated at the low levels of TRL where market or application considerations are not yet pertinent.

ESA currently carries out almost all European space-related R&D leading to prototypes and operational systems. These systems are then commercialised by the industry that participated in those activities and exploited by other European organizations (e.g. EU, EUMETSAT).

While there is no guarantee regarding the return of the contributions to the EU and EUMETSAT, the contribution to ESA has a guarantee of at least 95 % return of the funds contributed (minus the ESA costs to implement, technically follow-up and monitor the activities). What can be observed in the contributions of the Czech Republic to the EU (Space) and EUMETSAT is that little has been returned in the form of contracts or expenditures in the Czech Republic due to lack of ready capabilities of its industry to compete in these activities. However, the return of these contributions is being slowly increasing due to the participation of Czech industry in ESA activities where they develop the technologies and products necessary to win contracts in the EU and EUMETSAT. Especially ESA optional programmes play the key role in further development of Czech capacities and capabilities. However without keeping a level of the contribution to ESA optional programmes at appropriate level, there is extremely low chance that the investments of the Czech Republic to the EU and EUMETSAT space activities will ever come back in industrial contracts to build the operational satellites and spacecraft service platforms. However, in both cases, as far as the accessibility of satellite data and information is concerned, the significant indirect return on investment of these activities is assumed.

Science missions (funded only through ESA's mandatory contributions) have little recurrence (as an example, an X-ray or Infra-red space telescope, as may be expected, occurs only around every 20 to 25 years). ESA Member States and their industry can afford these science missions only if most of the required technologies are already available or their development is started early. These technologies are developed and matured first through some of the ESA Mandatory Activities. However, industrialisation and commercialisation of the developments that lead to economic sustainability in the global market are done through targeted ESA optional programmes. On the other hand, ESA's science missions have also important long-term benefits. Even the non-recurring missions bring extensive high-technological work into the upstream national industries, which thus gain heritage and opportunities for commercialization of the know-how in the hardware and software domains. Moreover, scientific missions foster the growth and development of the scientific communities of ESA Member States.

For supporting sustainable growth of the capacities and capabilities of the Czech industry and academia, their competitiveness and their preparedness to participate in European or wider

[3] Space is an area of economic activity with the highest potential for innovation due to the demanding environment of outer space to which the technologies have to be adjusted and due to technology push from cutting-edge technologies that are characteristic for preparation and implementation of technologically demanding space missions. Ultimately the companies take advantage of knowledge and experience gained during space technologies development in their core business, which stimulates new innovations outside space sector.

international programmes, the national space programme plays a crucial role. Although there is no national space programme in the Czech Republic nowadays, from the perspective of effective control the "Framework project implementing ESA's support of space-related activities in the Czech Republic" and PRODEX programme (see Chapter 4.4), both implemented through ESA using its expertise and competences, partially substitute the role of the national space programme. National space programme is essential for involvement of the Czech Republic in the strategic activities that cannot or should not be funded via traditional ESA programmes or activities.

1.3 SOCIAL AND ECONOMIC BENEFITS OF SPACE

Space activities are generally characterised by their high technological content, multi-disciplinarity, complexity, extreme visibility and often high cost. The two most important reasons why investment by the Czech or European tax-payer in space is of strategic importance are of social and economic nature.

Social benefits

In the social domain, space is of fundamental importance for the independence, security and prosperity of Europe. It is an enabling tool that gives decision-makers the ability to respond to critical challenges such as global climate change and global security.

Space technologies, products and services are an important part of everyday life. Weather forecasting, air traffic control, navigation, global communications and broadcasting – these and many other essential activities would be almost unthinkable today without satellite technology.

Modern weather forecast would be impossible without the satellite data that allow a global view of the Earth and its environment. Earth observation satellites are today an essential tool in the understanding of the physics and chemistry of the Earth's, atmosphere, land surfaces, oceans, geology and inner core.

In disaster forecasting, mitigation, management and assessment, satellite data play a fundamental role by providing the measurements for forecasting (e.g. storms) but also supplying the information to identify affected regions or infrastructure spared or destroyed (e.g. roads or bridges still open). It is also used to assess damage and to follow-up the recovery of the affected region (e.g. fires, floods, earthquakes, draughts – see Figure 1).

Applications include systems for increasing the safety of air traffic and monitoring the movements of aircraft and authorized road vehicles at airports, safety measures for operating railroad transport, monitoring of the location of special consignments (e.g. oversized cargo, live animals, dangerous goods, valuable cargo), enhancing of road safety, improvement of logistics system functions, information gathering necessary for traffic control, systems for the control of domestic ship navigation and optimisation of water traffic.

Civilian protection and emergency response uses global navigation satellite systems (GNSS) for localization of persons and assignment of resources for rescue operations of the highest priority, for localization of the area of emergency situations and catastrophes, for example contamination of the sea, chemical accidents, erosion processes, and alike.

Telecommunication satellites have been for many years one of the backbones of the global telecommunication infrastructure. Satellites broadcast the signals to our satellite TVs, transmit or receive, from our internet data to our phone calls, from data on the habits of wildlife to that from instruments in remote places. The internet revolution was a consequence of the communication revolution that space technologies made possible.

Satellite systems also enables the precise farming or effectively synchronise energy, IT or financial networks, etc.

Economic benefits

In the economic domain space brings a significant contribution to Europe's growth and employment and it provides indispensable enabling technologies and services for the knowledge society.

At this time of unprecedented economic challenges, space is proving to be an anchor of stability and a counterbalance to negative trends. Space-based services are having an increasing effect on our way of life. Competitiveness fosters growth. Increasing the competitiveness of the European space industry and operators on world markets, whether in infrastructures or services, and increasing the competitiveness of space-based services compared to ground-based services will contribute to growth in Europe.

One can, in principle, divide the economic impact in 2 different factors. The first one comes from the increase of revenues in industry stemming from increase of productivity or efficiency of the industrial processes, new ideas leading to new products or new markets. The second factor is related to societal impacts arising from increase in employment, savings due lives saved, better management or streamlining of societal infrastructure (e.g. weather, storm, flood forecast), information dissemination, etc.

Floods damages in the Czech Republic		
Year	Damages (bil. CZK)	GDP percentage
1997	62.6	3.3%
1998	1.8	0.1%
2000	3.8	0.2%
2001	1.0	0.0%
2002	73.3	2.9%
2006	6.2	0.2%
2009	8.5	0.2%
2010	15.0	0.4%
Total	172.2	

Figure 1: The table shows the impact on GDP induced by floods. Using of information provided by satellites contributes to better coordination of crisis management and rescue teams which helps to protect the property, save lives and reduce the impact of disasters in general. It is anticipated that the reduction of impacts could be in grade of percent. Source: Patria Finance

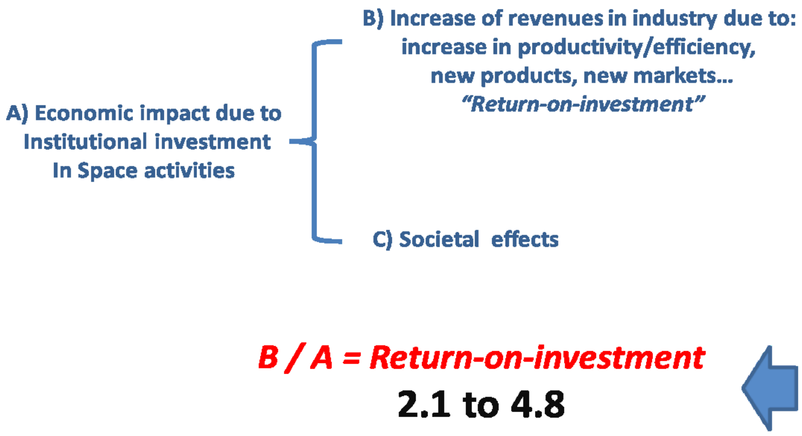

Figure 2: Space value chain. Source: OECD

The first factor can be seen as a return-on-investment of space activities of the public investment. This return-on-investment of space activities is higher than in most other sectors of economic activity.

Several independent studies have shown the increased revenues in the economy due to public investments in space activities. Considering only economic impacts without societal ones, for each €1 invested in space through ESA (more global data is difficult to obtain) Norway had an impact of €4.8 in the period from 1985 to 2012, Denmark of €4.5 in the period 2000-2007, Portugal of €2.2 in 2000-2009 and Canada of €2.07 in 2000-2009. This economic impact is recognised by the OECD in their "Space Economy at a Glance" reviews published in 2007 and 2011.

Because of the different methodological approaches used, it is difficult to perform comparisons between countries. However, the economic impact observed is also similar to those observed by the OECD on a global scale when considering the pyramid of economic value chain associated with space activities and the public investment. The multiplier effect in this case, not considering societal effects, is similar to the economic impact obtained with the previously discussed detailed studies. The "industrial effects" shown at the left of the figure 3 are those arising from increase of productivity and competitiveness in industry, cost savings and new concepts and ideas associated with space activities.

It should however be said that this multiplier effect cannot be obtained without industrial involvement (as by consequence public investment) in the different sectors of the pyramid. This is due to the fact that without knowledge and expertise in the upper part of the pyramid (space upstream related to satellites, equipment, instruments, etc.) it is difficult to be successful in the lower part of the pyramid (down-stream) where the knowledge acquired in the up-stream is essential for competitive services and applications.

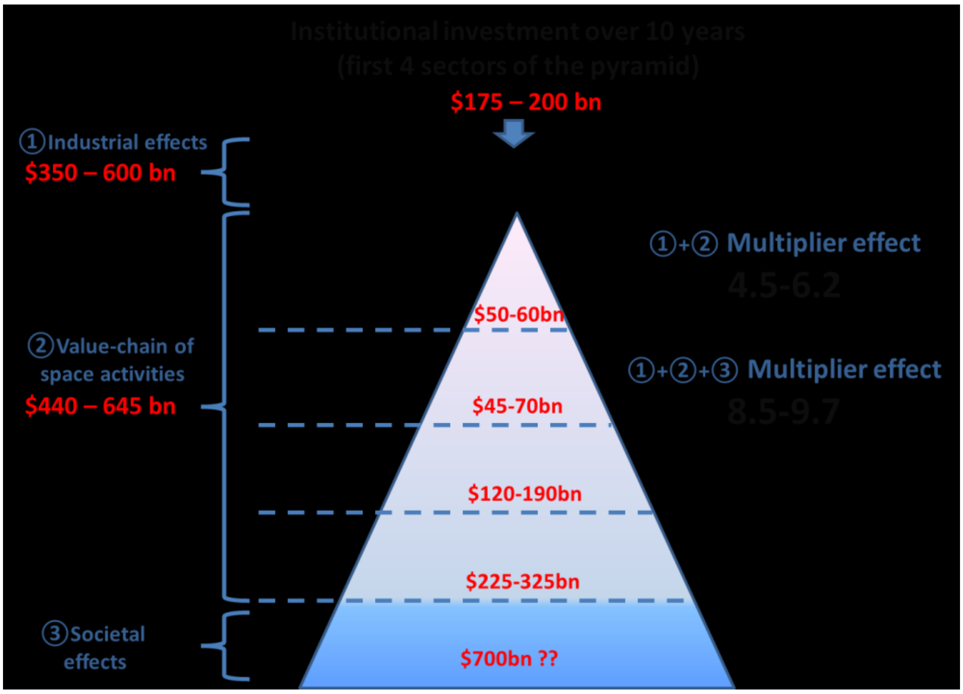

Figure 3: Space value chain. Source OECD

2 POSITION OF THE CZECH REPUBLIC IN SPACE ACTIVITIES

2.1 INSTITUTIONAL SETTING AND FUNDING

2.1.1 NATIONAL SETTING

2.1.1.1 Coordination Council for Space Activities

The Government of the Czech Republic in April 2011 entrusted the Ministry of Transport (MD) with the role of a coordinator of all space activities in the Czech Republic. For the purpose of coordination, the MD established the Coordination Council for Space Activities which consists of high-level representatives of the MD, Ministry of Industry and Trade (MPO), Ministry of Education, Youth and Sport (MŠMT), Ministry of the Environment (MŽP), Ministry of Foreign Affairs (MZV), Ministry of Defence (MO) and Office of Government of the Czech Republic (ÚV ČR). Other ministries and governmental bodies or other relevant public entities such as Ministry of Finance (MF), Ministry of Regional Development (MMR), Ministry of the Interior (MV), Ministry of Agriculture (MZe), Czech Telecommunication Office (ČTÚ), Czech Office for Surveying, Mapping and Cadastre (ČÚZK), National Cyber and Information Security Agency (NÚKIB), National Security Authority (NBÚ), State Office for Nuclear Safety (SÚJB), Czech Science Foundation (GA ČR), Technology Agency of the Czech Republic (TA ČR) or CzechInvest are also advised to participate in the Coordination Council when appropriate. There are also entities which might also contribute to implement the NSP, such as Industrial Property Office (ÚPV), State Mining Administration (ČBÚ), Czech-Moravian Guarantee and Development Bank (ČMZRB) and Export Guarantee and Insurance Corporation (EGAP).

The Coordination Council has also established cross-sectional committees as an interface with industry and academia – "Industry and Applications" and "Science Activities". The "Security and International Relations" Committee deals with security and international aspects of space activities.

2.1.1.2 Division of Main Competences in Space Activities

MD	Overall national coordination in space activities; responsibility for national regulatory and support activities, including preparation and implementation of the NSP; overall responsibility for membership in ESA; responsibility for EU space policy and EU space programme (in Copernicus shared competence with MŽP), including interface to the European GNSS Agency (GSA); responsibility for EU framework programmes for research and innovation – priority space; interface to CEN/CENELEC in space standardisation, contact point for international cooperation in space; coordination of space downstream sector development, including responsibility for such a development in transport, responsibility for membership in European Organization for the Safety of Air Navigation (EUROCONTROL), International Maritime Organization (IMO), International Civil Aviation Organization (ICAO) and International Mobile Satellite Organization (IMSO), cooperation with MZV in UN Committee on the Peaceful Uses of Outer Space (COPUOS), responsibility for Membership in its Science and Technical Subcommittee and cooperation with MZV in the UN COPUOS Legal Subcommittee, and other related matters.
MŠMT	Overall responsibility for education and R&D, including international cooperation in R&D; cooperation with MD concerning membership in ESA, overall responsibility for coordination EU framework programmes for research and innovation; responsibility for support of large research infrastructures and membership of the Czech Republic in international R&D organizations established under the international law (e.g. European Southern Observatory, ESO and European Organization for Nuclear Research, CERN) and/or European legal framework of ERIC, responsibility for management of general programmes for support of international cooperation in R&D and managing authority of Operational Programme Jan Amos Komensky
MPO	Overall responsibility for state industrial and trade policy and for support of business and industry; responsibility for electronic communications, responsibility for membership in Intersputnik, International Telecommunication Union (ITU), International

	Telecommunications Satellite Organization (ITSO) and EUTELSAT IGO; managing authority of Operational Programme Competitiveness. Support organizations: Investment and Business Promotion Agency (CzechInvest) and Czech Trade Promotion Agency (CzechTrade).
MŽP	Responsibility for Membership in Group on Earth Observations (GEO) the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecast (ECMWF) and the World Meteorological Organization (WMO), responsibility for downstream sector development in environment protection; co-responsibility for Copernicus programme. Support organizations: Czech Environmental Information Agency (CENIA) and Czech Hydrometeorological Institute (CHMI).
MZV	Responsibility for Czech foreign policy and international law; overall responsibility for Membership in UN COPUOS, including responsibility for Membership in the UN COPUOS Legal Subcommittee; diplomatic assistance and support.
MO	Responsibility for defence of the Czech Republic; control over the Armed Forces of the Czech Republic and Military Intelligence that includes SATCEN ČR; responsibility for management of national defence applied R&D; responsibility for membership of the Czech Republic in the European Defence Agency (EDA) and the North Atlantic Treaty Organization (NATO), responsibility for downstream sector development in defence.
ÚV ČR	Coordination of European policies; executive secretariat of governmental Research, Development and Innovation Council.
NÚKIB	Guarantee and regulation of cyber and information security, including Public Regulated Service of Galileo.
ČÚZK	Responsibility for operation of public Network of Permanent GNSS Stations of the Czech Republic (CZEPOS) which provides data from GNSS and following services based on them for precise positioning useable in a number applications and technologies in different branches, especially in land surveying, precise agriculture, GIS and navigation, etc.
ÚPV	Responsibility for information support and awareness rising in the field of IPR.

From downstream applications user perspective, the relevant state entities are especially the following: MD (including Road and Motorway Directorate, Railway Infrastructure Administration, Air Navigation Services), MŽP (including CENIA and CHMI), MO (including Army, Military Police and Military Intelligence); MZV, MV (including Police, Fire Rescue Service and Office for Foreign Relations and Information); MZe, MF, MMR (including Mountain Rescue Service), ČÚZK, SÚJB and ČBÚ.

It should be also noted that Military Intelligence has established a new satellite centre SATCEN ČR. The main tasks of SATCEN ČR are to provide specific, detailed and accurate information about the location of objects and areas of interest. Its outputs will support both the Czech Armed Forces and NATO, as well as the Integrated Rescue Service and other state institutions. For the the defence and military purposes, the GPS system has been used exclusively (namely the Precise Positioning Service - PPS), since it is the only GNSS system, which meets the security requirements for NATO combat operations (MC 139/3 Policy on Satellite Navigation Services for NATO Military Operations).

2.1.2 Membership of the Czech Republic in Relevant International Organizations

The Czech Republic is a member state of a number of international organizations, which implement their own space missions and activities or have a stake in space activities from technological, science or another point of view or which are usually users of space systems or their technologies.

2.1.2.1 Organizations Directly Involved in Space Activities

These organizations implement their own space missions and activities. They are usually oriented to upstream and midstream activities but they also support in different measure the downstream sector. They usually own their satellite systems and often operate also these systems.

Upstream covers all areas directly pertinent or supporting satellites, launchers, satellite operations and ground-segment, midstream represents components and technologies for support space missions utilization and downstream refers to industrial activities which use the space infrastructure and space based data to provide tools and services for general users.

A) ESA

ESA is an intergovernmental organization with the mission to provide for and to promote, for exclusively peaceful purposes, cooperation among European States in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems.

ESA elaborates and implements its long-term space policy through its programmes and its industrial policy. ESA coordinates and supports the global competitiveness of European industry by coordinating European and national space programmes and through its programmes, by maintaining and developing space technology and encouraging the rationalisation and development of an industrial structure appropriate to market requirements.

ESA activities are performed within programmes of two different types:

- Mandatory Activities which include the agency's basic activities as studies on future projects, technology research, shared technical investments, information systems and training programmes and they are organized mainly through the Science Programme, the Discovery, Preparation and Technology Development Programme and ESA's technical and operational infrastructure. Participation and contribution of each Member State is obligatory and proportional to its GDP.
- Optional programmes which cover space domains like Earth observation, satellite navigation, telecommunication, launchers, human spaceflights, microgravity, exploration, technology development, etc. including the development of space applications. Each Member State may participate in and may contribute according to its own interests and financial resources. Therefore ESA Member States see in the optional programmes the opportunity to pursue their national strategies in a targeted and more controlled manner than in the Mandatory Activities.

Typically more than ¾ of the member states' contributions to ESA's budget is dedicated to optional programmes. Especially the optional programmes help the Member States to build their industrial capacities and capabilities to be able to implement Mandatory Activities and to be competitive worldwide.

In general, 90-95 % of ESA's budget is spent on contracts with industry. Industrial policy of ESA is therefore essential tool to motivate Member States to invest in ESA's programmes. The motivation is driven by so called industrial return or geo-return (in the context of EU this approach is called *juste retour*). To monitor and control the geo-return, ESA keeps track of geographical distribution of all contracts among its Member States as well as the technological value of the contract. From this statistical data a return coefficient is derived for each Member State as ratio of actual and ideal weighted value of contracts. Weights were established to represent how interesting and important contracts are in terms of technology. Ideal value is pro rata proportional to contribution of each Member State to each concerned programme. In ESA Mandatory Activities and in each of its optional programmes ESA ensures return coefficient reaches at least 84 % of the Member State contribution (minus ESA internal costs). The contribution returns to the Member State in the form of contracts. Many optional programmes have even higher guaranteed percentage. ESA further ensures that, when all Mandatory Activities and optional programmes are taken into account, the return coefficient for each Member State will be at least 95 % at latest at the end of 2024 (similarly 91 % and 93 % are guaranteed by ESA for respectively the end of 2019 and 2022).

The emphasis on geo-return is an absolutely unique feature of ESA, which motivates Member States to fund ESA activities. For the Czech Republic geo-return is especially important as it guarantees the return on Czech contributions made to ESA back to the Czech Republic – even when Czech industry – for the time being – may be less competitive vis-à-vis the rest of Europe.

B) EU

With the Treaty of Lisbon, space policy also becomes a key area of interest of the EU with very high political, security and economic potential.

The strategic objectives of EU´s space policy are namely:

- To develop and exploit space applications serving Europe's public policy objectives and the needs of European enterprises and citizens, including in the field of environment, development and global climate change;
- To meet Europe's security and defence needs as regards space;
- To ensure a strong and competitive space industry which fosters innovation, growth and the development and delivery of sustainable, high quality, cost-effective services;
- To contribute to the knowledge-based society by investing strongly in space-based science, and playing a significant role in the international exploration endeavour;
- To secure unrestricted access to new and critical technologies, systems and capabilities in order to ensure independent European space applications;
- To secure independent, reliable and cost-effective access to space.

These objectives are linked to a number of present EU policies (for example, transport policy, information society, environment policy) and overlap with a multitude of scientific fields of the General Programmes (space, traffic, environment, information and communication technology, nanotechnology, and materials).

EU currently (2019) governs the following space activities: Galileo, EGNOS and Copernicus and the Space Surveillance and Tracking (SST). EU also supports space activities in the framework of Horizon 2020 (for 2014-2020) and prepares its successor Horizon Europe (for 2021-2027).

EU procurement is governed by the Financial Regulation and its Implementing Rules which are in line with the WTO Agreement on Government Procurement. These instruments embody the principle of non-discrimination and do not allow any form of juste retour (or geo-return).

The Czech Republic inherently participates in all EU space related activities.

The Czech Republic also actively supports the strengthening of the role of GSA especially when the use of its existing infrastructure for the whole EU Space Programme is concerned to avoid any unnecessary duplications and budget increases. The seat of the GSA was relocated to Prague in September 2012.

Since 2021 the regulation establishing the EU Space Programme and the EU Agency for the Space Programme (EUSPA) should come into force. The regulation will unify all the current (2019) above mentioned EU space programmes and frameworks (called components in the future) into one EU Space Programme. In addition of current satellite systems will be also establish the new components of the EU Space Programme, i.e. GOVSATCOM and Space Situational Awareness (SSA). The leading force of the EU Space Programme is the European Commission, which takes the overall responsibility, ensure a clear division of tasks and responsibilities and coordinate the activities among various entities involved in the EU Space Programme.

The regulation anchored also strong role of ESA on the EU Space Programme, among the others coordination of the space component and implementation for Galileo and EGNOS and for the Copernicus space component and its evolution, design, development and construction of that infrastructure and related procurement; as regards to all the components of the EU Space Programme with research and development activities in upstream.

EUSPA

EUSPA will play the significant role in the implementation of the EU Space Programme (see also Chapter 4.4.2.2.1). EUSPA will be among others responsible for the security accreditation, ensure operation of Galileo Security Monitoring Centre (GSMC), market development, promotion activities, activities relating to the market uptake and users´ needs coordination, communication of the EU Space Programme etc. EUSPA should also ensure the management and exploitation of EGNOS and Galileo, overarch coordination of GOVSATCOM user needs, and implement activities relating to the development of downstream applications based on the components of the Programme and other tasks entrusted by the European Commission.

EUSPA will also provide expertise to the European Commission, including for the preparation of the downstream space-related research priorities.

C) EUMETSAT

EUMETSAT is an intergovernmental organization focused primarily on continuous, long-term weather and climate-related satellite observations, data processing and archive services, and distribution of its data, images and retrieved products to the National Meteorological Services of its Member and Cooperating States in Europe, as well as to other users worldwide.

The service provided by EUMETSAT helps to enhance and safeguard the daily lives of European citizens. They aid meteorologists in identifying and monitoring the development of potentially dangerous weather situations and in issuing timely forecasts and warnings to emergency services and local authorities, helping to mitigate the effects of severe weather and protecting human life and property. This information is also critical to the safety of air travel, shipping and road traffic, power distribution, and to the daily business of farming, construction and many other industries.

EUMETSAT's key partner in developing and manufacturing of satellites and supporting technologies is the ESA. EUMETSAT's main operational programmes are focused on meteorological observations of the Earth's atmosphere and oceans.

Mandatory programmes are the main, most important programmes required to continue the provision of observations from geostationary and polar orbits or other programmes as defined as such by the EUMETSAT Council. Financial contributions of Member States to mandatory programmes are proportional to the Gross National Income (GNI) of the individual Member States. In case of optional programmes, any Member State has the opportunity to participate in these, in accordance with its interest.

Besides the native mandatory and optional programmes, EUMETSAT (together with ESA) is one of the key operational components of the Copernicus space segment. Some of the Sentinel instruments or satellites are operated on behalf of the EU by EUMETSAT, which also plays a key role in data ingest, storage, processing and distribution (for atmosphere observation related Sentinel missions).

EUMETSAT doesn´t apply the industrial return or geo-return policy. Due to the partnership of EUMETSAT and ESA in development of satellites, there is an opportunity to take advantage of synergy between ESA and EUMETSAT meteorological programmes. In frame of ESA´s programmes and based on EUMETSAT's specifications are developed functional prototypes of each new series of meteorological satellites. Other satellites of the same series are next procured by ESA on behalf of EUMETSAT. In case of participation in ESA´s meteorological programme there is the chance to reach the return-on-investment expressed by coefficient 4-5 (depends on in concrete case).

The Czech Republic takes part in EUMETSAT mandatory programmes but it does not participate in its optional programmes so far. The Czech Republic can take part in all EUMETSAT's industrial, technological and research projects and tenders.

2.1.2.2 Organizations with a Stake in Space Activities

These organizations have a stake in space activities (from technological, science or another point of view). Some use the space systems as a key tool for their mission or activities, others benefits from synergies between space and ground systems. They can also operate their own satellites. Their activities have strong synergies with activities of organizations directly involved in space activities. They may also serve as platforms for creating of environment or rules for using of outer space.

Among these organizations belong especially ESO, NATO, Intersputnik, CEN/CENELEC, UN COPUOS, GEO, EUROCONTROL, WMO, IMO, ICAO, CERN, IMSO, ITU, ITSO and EUTELSAT IGO.

There are some organizations and entities relevant to space in which the Czech Republic is not a member at the state level but at academia and/or industry are involved. Among such organizations belong especially Committee on Space Research (COSPAR), International Astronomical Union (IAU), and International Astronautical Federation (IAF).

2.1.2.3 *Organizations and Entities with Limited or no Participation of the Czech Republic*

There are still some organizations and entities relevant to space in which the Czech Republic is not a member.

A) ECMWF

ECMWF is an international organization which was established to pool the scientific and technical resources of Europe's meteorological services and institutions for the production of medium-range weather forecasts and of the economic and social benefits expected from it. ECMWF provides weather services with medium-range forecasts of global weather to 15 days ahead as well as with monthly and seasonal forecasts. ECMWF runs a sophisticated medium-range prediction model of the global atmosphere and oceans. ECMWF is one of the most advanced users of satellite data for weather prediction and climate monitoring and collaborates closely with satellite data providers such as the EUMETSAT and the ESA, the NASA, and the NOAA.

B) Eurisy

Eurisy is a non-profit association of space agencies which raises awareness of emerging satellite applications which can help professional communities in many sectors of application, e.g. transport, risk management, habitat protection, energy, climate change, Internet of Things etc. Eurisy supports potential end-users of satellite applications by leveraging its network to make available experience and expertise for them.

2.1.3 *BILATERAL INTERNATIONAL COOPERATION*

The Czech Republic has concluded a number of international agreements in the field of economic or scientific cooperation. The agreements are of general nature. The list of the agreements is enclosed in Annex C.

The Czech Republic has concluded Treaty between the Czech Republic and France related to the cooperation in the area of exploration and use of outer space for peaceful purposes. The detailed implementation plan is still to be defined.

In 2010 the MD and the Brazilian Space Agency (AEB) signed the Letter of Intent aiming to explore opportunities for co-operation in national and international space technologies.

The MD has signed a Memorandum of Understanding with Ministry of Economy of Luxembourg on a cooperation in the frame of space resources exploration and utilisation.

2.1.4 *FUNDING OF SPACE ACTIVITIES IN THE CZECH REPUBLIC*

Since there is no specific national tool in the Czech Republic which would be used directly to support space activities, the Czech Republic primarily participates in space activities of international organizations as ESA, EU and EUMETSAT. Since 2017, an ESA 3rd party programme, the "Framework project implementing ESA's support of space-related activities in the Czech Republic" (so called Czech 3rd Party Framework Project, C3PFP) is being implemented using ESA's expertise and competences. The C3PFP substitutes to a certain extent a national space programme.

As far as the international organizations are concerned, there is no single source of funding of their space activities in the Czech Republic.

Payment of the contributions to ESA is currently divided between MD and MŠMT. For this purpose the MŠMT uses its budget for international cooperation in R&D to fund contributions to ESA Mandatory Activities (Science Programme and Basic Activities), Guiana Space Centre (CSG), and selected R&D oriented optional programmes. MD uses its general budget to fund selected industry oriented optional programmes and the C3PFP.

Since the ESA optional programmes periods are multiyear but timely limited, there is the need to sustainably subscribe to new optional programmes and continue in the next phases of the existing ones. Otherwise they will end in few years without continuation.

Actual annual level of funding of ESA activities and programmes (2019) is the following (the amounts may change due to changes of exchange rate between EUR and CZK):

- 315 million CZK (i.e. €12.25 million) for Mandatory Activities, contribution to CSG, and selected R&D oriented optional programmes;
- 555 million CZK (i.e. €21.5 million) for industry oriented optional programmes;
- 375 million CZK (i.e. €14.5 million) for C3PFP.

For next years, the following levels of ESA funding are anticipated (in mil. CZK):

	2020	2021	2022	2023	2024	2025
MD: Industry oriented optional programmes, C3PFP	1 205	1 205	1 205	1 205	1 205	1 205
MŠMT: Mandatory Activities, contribution to CSG, R&D oriented optional programmes *	325	325	325	325	325	325
TOTAL	**1 530**	**1 530**	**1 530**	**1 530**	**1 530**	**1 530**

*Note: In the implementation of NSP 2020, MŠMT will always proceed in accordance with the capacities of the budget section 333 and approved budget expenditures of Czech Republic for research, development and innovations. An increase of budgetary allocation for the Czech membership in ESA above the level of 325 million CZK will respect the inner structure of allocations of institutional support funding to international cooperation in R&D, so that increases in budget for the Czech membership in ESA do not negatively impact Czech Republic's involvement in other activities, initiatives and programmes of international cooperation in R&D.

EU space activities are funded from EU budget. The Czech Republic's share is approx. 1.2 % of its total EU budget. The payment is made by the MF.

The MŽP is responsible for funding of the membership fee of the Czech Republic to EUMETSAT. For 2019, the contribution of the Czech Republic is approx. 130 million CZK (i.e. €5.1 million).

United Nations Office for Outer Space Affairs (UNOOSA) is funded from the UN budget. The Czech Republic's share is approx. 0.31 % of the total UN budget. The payment is made by the MZV.

2.2 Czech Industry and Academia and Their Current Space Capacities and Capabilities

Past heritage allowed the Czech scientific community to continue in the research space activities throughout the changes of the economic model in the Czech Republic. In contrast, the Czech space industry had to be developed with significant effort from the onset. Moreover, the scientific community had very limited prior experience in cooperation with industry and in commercialization of its outputs. The know-how in transfer of knowledge from academia to industry and vice versa had to be gained on both sides – a process which is continuing up to this date. Some of the crucial aspects of the know-how in efficient cooperation between the industry and academia, which both need to master, are the work with clearly defined deliverables and timescales together with in-detail documented outputs on the side of academia, and identification of commercially applicable outcomes of the research work on the side of industry.

It is well understood in Europe, that it is mainly SMEs which drive innovation and creation of jobs. Participation in ESA projects enables SMEs to develop cutting edge technologies, use existing wealth of technologies developed previously, and learn fast by participating in international teams with very experienced space partners. Exploiting this know-how to increase the competitiveness of Czech SMEs and to develop new indigenous products or services does not happen overnight. However, Czech companies are making significant progress faster than their competitors might have expected.

Czech industry is developing a portfolio of competencies with an indigenous and sustainable supplier base in the Czech Republic. This is being done in both the manufacturing and R&D phases and in accordance with the knowhow and possibilities of the Czech Republic. Successful projects are thus creating a pathway to compelling new capabilities for the Czech space industry and long-term growth prospects for the entire economy of the Czech Republic.

2.2.1 *Czech Industry*

In the Czech Republic, there are several industrial associations with their members involved in space activities related to up-, mid- and down-stream. The associations protect common interests of their members and support the coordination and cooperation among them, international cooperation, common communication, public relations etc. The main associations related to space activities are the following:

- Czech Space Alliance (ČVA)
- Association of Aerospace Manufacturers of the Czech Republic (ALV)
- The Association for Transport Telematics (SDT, known abroad as ITS&S)
- GNSS Centre of Excellence (GCE)

There are also other entities indirectly related to space activities in the Czech Republic:

- Czech Chamber of Commerce
- Association of Small and Medium-Sized Enterprises and Crafts of the Czech Republic (AMSP)
- Confederation of Industry of the Czech Republic (SPCR)

In these associations but also outside of them there are individual companies in the Czech Republic which capacities and capabilities are discussed in this Chapter. Within the first ten years of the Czech membership in ESA there have been about 70 companies which were awarded an ESA contract or participated in such a contract through their partners. These companies are mainly focused on upstream. Looking beyond ESA contracts, the capacities and capabilities of the Czech Republic especially in downstream sector are many times higher.

2.2.2 *Czech Academia*

Academia involved in space activities in the Czech Republic can be divided into two groups:

- Czech Academy of Sciences (CAS) and its institutes: Their role is to conduct basic research in a broad spectrum of the natural, technical and social sciences, and the humanities. Scientists of the CAS institutes also participate in education, particularly through doctoral study programmes for young researchers and by teaching at universities as well. The CAS also fosters collaboration with applied research and industry. The integration of Czech science into the international context is being promoted by means of numerous joint international research projects and through the exchange of scientists with counterpart institutions abroad. The CAS has established its Council for Space Activities as a platform where scientists from different public research institutions coordinate their space activities. These are:
    - Institute of Physics;
    - Astronomical Institute;
    - Institute of Atmospheric Physics;
    - Nuclear Physics Institute;
    - Institute of Plasma Physics;
    - J. Heyrovsky Institute of Physical Chemistry;
    - Institute of Photonics and Electronics;
    - Institute of Rock Structure and Mechanics;
    - Institute of Computer Science;
    - Institute of Geophysics;
    - Institute of Psychology.
- Universities: Several Czech universities have activities that are related to space activities and that could play an important role in the support of the development of industrial capabilities (up-, mid and down-stream). Worth of special mention are:
    - Czech Technical University in Prague;
    - Brno University of Technology;
    - Charles University;
    - Palacky University in Olomouc;
    - University of West Bohemia;

- University of South Bohemia in České Budějovice;
- Czech University of Life Sciences in Prague;
- VŠB – Technical University of Ostrava;
- Masaryk University;
- University of Pardubice;
- J. E. Purkinje University in Ústí nad Labem;
- Mendel University in Brno.

Within the first ten years of the Czech membership in ESA there have been about 20 academia institutes which were awarded an ESA contract or participated in such a contract through their partners.

2.2.3 Current Space Capacities and Capabilities of Czech Industry and Academia

The current Czech capabilities and capacities could be employed in the space upstream, midstream and downstream reflecting actual or arising market opportunities. The further support and development of the existing eco-system that already has expertise with a strong background in the space domain should also foster the re-use of products across adjacent markets, in order to increase sales volume and thus secure additional future resources for future R&D activities.

2.2.3.1 Upstream

The upstream in space includes all areas directly pertinent to or supporting satellites, satellite operations, launchers, and ground-segment – both technology development and mission planning and implementation.

Number of technologies, products and services are of general purpose nature, meaning they can find use in number of space domains (and in non-space applications).

Mechanical Systems for Space Applications

Czech space industry has a long-term heritage in mechanical systems for space applications. A good example of their current capability is the supply of the solar array hinges for the next generation of Iridium satellites. Other areas in development are pointing mechanisms for antennas and thrusters, and mechanical structural elements.

It is highly recommended to utilise the experience in design, testing and manufacturing of mechanical systems in both ESA and commercial projects.

Overall competencies in this area include e.g.:

- Stress, thermal and fluid dynamic calculations;
- Fatigue life and fracture mechanics evaluation;
- Design of highly loaded components and their optimization;
- Numerical computation involving complex physical effects;
- Thermal design and analysis of the space subsystems;
- Structural evaluation of space components;
- Aerodynamics, aero elasticity, acoustics;
- Climatic, mechanical and life-time testing of components, parts and materials;
- Additive manufacturing;
- Composite production and bonded sandwich structures, epoxy adhesives for extra high strength bonds, epoxy resins for lamination, pultruded composite profiles and sandwich panels;
- Production and delivery of qualified mechanical parts, assembled modules and subsystems.

Flight Hardware Design and Production

Overall competencies in the area include e.g.:

- Development of digital circuits and single-chip microcontrollers;
- In-flight use of wireless sensors;
- System health monitoring (SHM);
- Design of the mechanical parts and/or entire systems;
- Space hi-rel electronics cleanroom manufacturing activities;

- Products for crystal chemistry, study of crystal growth and solidification processes, growth of crystals for technical applications (optics including x-ray, acousto-optics, electro-optics, adaptive and adaptive optics, free-form optics, thin layers, polarisers, laser applications, fine mechanics, etc.);
- Equipment for material sciences and technology in space;
- Development and manufacturing of apparatuses and devices according to specific requirements and various space applications, including mechanics, optics and electronics including use of COTS components suitable for space environment.

Inertial Sensors for Space Application

It is worth to mention that the micro-accelerometers successfully deployed on ESA's SWARM satellites were developed and manufactured in the Czech Republic. These micro-accelerometers were designed to extremely high specifications aimed for the specialized scientific purposes. As such, these accelerometers are currently not suitable for direct commercialization. However, their development in the Czech industry brought significant benefits in form of heritage and know-how and increased the visibility of the Czech space activities within ESA and further.

Inertial navigation sensors are a good example of a cross-domain product family in a high tech technology area with significant economic added value. As the navigation sensors are comprised of multiple technology domains it provides another excellent area for fostering the cooperation between Czech industry, Czech research institutes and Czech universities participating in advanced applied R&D topics.

The ultimate goal is the development of family of Czech space qualified inertial measurement and navigation units using MEMS sensors – independent of restrictive foreign export control rules. If the MEMS gyroscope technology is developed in the Czech Republic, the technology will fall under licensing rules of the Czech Republic and the EU.

Electric Power and Controls for Space Applications

Main directions of development for European satellites are currently the following:

- Performance improvements;
- Cost reduction;
- EU Competitiveness and independence.

Clear trend to increase of the satellite on-board power is emerging, caused by a transition to electric propulsion, increased consumption of the payload equipment, and availability of higher mass efficiency of power sources, typically solar panels.

This desire to handle more power on-board the spacecraft, along with demand for lower cost, results in need for higher power density electronic components – the launch cost, dependent amongst other aspects on the weight of the satellite, is a significant share of the total lifetime cost of satellites. The emerging need to launch all-electric satellites (i.e. without chemical thrusters) necessitates a development in the areas of electric propulsion and energy storage capable of high power release or generation. On the other hand the advancements in power electronics are enabling applications of electrical pumps for large satellite apogee engines and thrust regulated lander engines, for which Czech industry is developing electric pump technology (also applicable to launchers).

Substantial synergy between the space and aeronautics development exists and could open opportunities.

The specific areas, where the synergy is evident could be:

- Power management, including conversion and distribution (e.g. Power Processing Unit, Power Control Unit, Power Control and Distribution Unit, Advanced monitoring such as Electrostatic Discharge monitoring and mitigation);
- Electric actuation (e.g. Electric Motors, Attitude Actuators – Reaction Wheels, Control Moment Gyros, Flow Control Units, Electronic Pressure Regulators, Thrust Vector Control Systems);
- Energy storage systems (including energy accumulation and generation) (e.g. Battery Systems including battery management, Innovative concepts of energy storage and possibly capacitors)

- Thermal management (e.g. Cryo-Cooling solutions, Heaters, Heat Exchangers);

However, this is an area of very strong competition with several already established European players.

Software

Over all competencies in this area includes e.g. following activities:

- On-board software:
  - Flight Software for various missions;
  - Complete software packages (developed through the complete development cycle from requirements definition, through architectural design, detailed design, implementation, delivery and acceptance phases);
  - StartUp SW, Mission critical SW & Application SW);
- Ground segment software for ESA Ground Station such as Satellite Control Systems, Mission Control System and EGSE (e.g. for ESTEC, ESTRACK, etc.). Software for ground segment infrastructures e.g. robotization of antennas and telescopes, control systems development, tracking software.
- Software development for the Earth Observation and Navigation Services Infrastructure.

Simulation and Testing

Over all competencies in this area (existing for the aeronautical sector) includes e.g.:

- Stress, thermal and fluid dynamic calculations;
- Fatigue life and fracture mechanics evaluation;
- Validation of highly loaded components and their optimization;
- Numerical computation involving complex physical effects;
- Thermal design and analysis of the space subsystems;
- Structural evaluation of space components;
- Climatic, mechanical, aerodynamics, aero elasticity, acoustics and life-time testing of components, parts and materials.

On-board Systems

Avionics or aviation electronics is the heart of any spacecraft (S/C) or aircraft (A/C), and it is typically controlling all the operations of a vehicle and its vital sub-systems. The term avionics refers to all the electronics-based equipment in S/C, and typically includes on-board data system, along with its on-board computer (OBC) and remote interface units (RIU), Attitude and Orbital Control System (AOCS), along with its software, sensors and actuators, flight software, payload data handling, interfaces, and communication services and protocols.

More specifically, next generation (NG) on-board platform systems (OBPS) is expected to integrate European non-dependent technologies and to be free of technologies subjected to U.S. export regulations. The NG OBPS include five major lines:

- Hardware platforms, including:
  - Platforms for control, data handling, guidance and navigation, payload processing;
  - Processing modules, based on contemporary packaging technologies, such as system-on-chip, multi-chip modules, system-on-package, and system-in-package;
  - Processing modules extensively integrating multi- and many-cores;
  - AOCS;
- Software platforms, including
  - Reference software architectures to enable software re-usability across different space missions and across space and aerospace market segments;
  - Mechanisms for ensuring time and space partitioning of S/C and/or A/C functions;
  - Attitude determination and control algorithms;
- Network interfaces/Data buses, including payload and platform buses, to take into account the growing need for high-speed interfaces, Time-Triggered Ethernet (TTE) networks;
- Modules to provide integrity of on-board data systems, such as:
  - Reference system architectures;

    - Remote interface units;
    - Network interface cards;
    - Integrated tool chains for acceleration of development, and verification and validation cycles, including tools for HW/SW co-design and end-to-end cycles;
- Integrated test-beds to enable application testing in a laboratory environment and thus early in development cycles.

According to already conducted surveys, some of the key differentiators are as follow:

- Increased processing capabilities;
- Reduced size, weight and power (SWaP);
- Implementation of functional services linked to on-board communication;
- Rationalization of interfaces;
- New architectures for lower level and application SW;
- Enhanced modularity and multi-instruments support capability;
- High data throughput links and increased memory capacity.

Further, there is number of technologies, products and services that are specific for particular space domain (and sometimes have non-space applications).

Laser Technologies

The Czech Republic has historical experience in developing various laser instruments for space. Czech academia in this respect is well recognized in ESA and further in areas of laser communication or laser tracking of space debris (photon detectors). Laser technology in the Czech academia is also used to study its interactions with meteorites in laboratory conditions and as a tool for their spectral and composition analysis. The Czech Republic is home to state-of-the-art laser facilities.

Building up on this know-how and critical knowledge, as well as the state-of-art R&D laser facilities, the Czech Republic possess unique capabilities to develop new laser instruments in disruptive areas of space technologies.

These capacities and capabilities should be further developed, to be also possibly used in space resources prospecting and analysis, space debris tracking, manoeuvring and removal or in far future interplanetary and interstellar travel.

Earth Observation (EO)

- Development of High Altitude Platforms/Pseudosatellites (HAPs) for Earth observation (EO);
- Development of high-tech optical systems incl. active and adaptive optics, associated fine mechanics a new materials with special properties (e.g. crystal growing, housing for optics, etc.);
- Cryogenic and coolers for cooling of the payload on EO satellites;
- SCOE, EGSE for EO satellites / missions;
- General technologies, which could be used for building of satellites / microsatellites.

Multi-constellation GNSS

There is a niche expertise in precise time and clocks, which usefully complements the GNSS. These skills are relevant for on-board management of atomic clocks or for precise time distribution through optical satellite networks. Apart from the R&D and technology side, there is a strong expertise in GNSS science, namely atmospheric effects on propagation of electromagnetic waves including GNSS. Another related domain of expertise is a space geodesy and precise orbit determination of satellites. Loosely related to GNSS is also a broader field of attitude and orbit control of satellites, where the Czech industry focuses on development of AOCS components like gyros and MEMS based inertial sensors.

Satellite Communication

Although SatCom is a focused space engineering domain, it also provides a broad range of excellent opportunities for fostering the development of industries from many different areas of expertise. It is the maturity of the SatCom market, which makes the difference and drives the overall evolution of the space industry. Czech industry possesses a strong expertise in SatCom airborne terminals development for both civil and military aviation including unmanned aerial vehicles (UAVs). The SatCom terminal and associated products like high power amplifiers, data links and security gateways are the core SatCom developments by Czech industry, which focus on safety critical air-ground data and voice communication for air traffic management. Another field of expertise is the newly emerging secured quantum optical communication, where academia possesses the theoretical knowledge, which helps to advance the unbreakable quantum encryption techniques, laser photon emitters and receivers and sensor heads. Apart from the above mentioned telecommunication products there is a long-term academic interest in modelling of electromagnetic field propagation through the atmosphere. Lastly, there is a number of space and ground hardware developments undertaken for the sake of communication satellites, but which have nothing to do with SatCom technology as such (super-capacitors, solar panels deployment mechanisms, antenna pointing mechanisms, propellant tanks and other components).

Launchers and Propulsion Systems

Current capabilities are based on existing local industrial capacities and capabilities and cooperation across entire industrial and R&D sectors (universities, research institutes). Industry already successfully benefited from cross domain synergies in the space, aerospace and automotive industries paving solid way to long-term benefits to the national economy. The utilization of technologies and suppliers from outside of the traditional space industry is one of the ways how to achieve this goal.

Czech industry is involved in manufacturing and integration of Ariane 5 booster parts, namely PAR2 and fairing rings, as well in development, manufacturing and integration of small payload dispenser, regulation valves and control electronics for Vega family of launchers. Components of new deep throttle rocket engine for Vega E are being developed in the Czech Republic. Additionally, production of Ariane 6 booster structures has been set up and production of first parts is ongoing. The Ariane 6 production ramp-up activities are about to start. Czech industry also delivered key elements for the Ariane 6 launch pad, in particular flames deflector installed in the flame trenches under the launch pad and electrically powered moving platforms for mobile gantry. Projects by Czech industry are underway to develop critical on-board software for processing Ariane 6 telemetry and subsystems for the Ariane 6 ground segment at CNES.

Another possible area of Czech interest may be in micro-launchers, especially associated with sounding rockets that is currently not yet addressed in ESA's Launcher programmes except for FLPP, and future space exploration missions.

Industry is currently advancing technologies in several promising areas:

- Mechanisms and composite and metallic structures;
- Low shock Hold Down Release Actuators;
- Monomers and polymeric materials (coatings, adhesives, casting resins);
- Synthesis and tailored surface modifications of nanoparticles;
- Nanocomposites and hybrid composites;
- Thermo-insulation materials;
- Multifunctional anticorrosive coatings;
- Embedded microcontrollers;
- In-flight use of wireless sensors;
- Structural health monitoring systems;
- Pyrotechnical systems;
- Separation systems for small satellites;
- Computational mechanics;
- System level design Launcher aerodynamics, aerothermodynamics, launch acoustics;
- Payload Fairing technologies;
- Isolation systems and payload comfort damping;
- High-performance Valves and control electronics;
- Inertial sensors for inertial navigation, on-board computer navigation and control systems Thrust Vector Control (TVC) technology based on electromechanical actuators;

- Electrically driven pumps for rocket propellants;
- High-performance valves for cryogenic rocket engines and their control electronics.

These technologies are linked to the possible future participation of the Czech Republic in ESA's next launcher development programmes.

Space Situational Awareness (SSA)

Czech academia and industry actively participate in ESA SSA programme, as well as in other initiatives related to the SSA problematics (mostly by sharing of observation and monitoring data and relevant scientific expertise).

Space Weather (SWE)

- Provision of SWE services (Solar activity forecasts, Real-time Ionospheric monitoring, Daily geomagnetic forecasts, Radiation dosimetry);
- SWE sensors exploitation (Solar white light and H-alpha imaging, Solar radio observation, Ionospheric measurement, Geomagnetic observations);
- SWE Application development (Ionospheric disturbance detection and monitoring, Magnetospheric research, geomagnetic disturbance forecasts, Dosimetry applications for crewed space missions);
- SWE sensors development (various fields);
- SWE studies and modelling;
- SWE data processing.

Space Surveillance and Tracking (SST)

- SST monitoring and cataloguing;
- SST data processing and Software applications development;
- SST Assets networking technologies;
- SST sensors development and qualification (optical and laser technologies).

Czech industry and academia are active in SST optical observation and processing. Regular campaigns are being performed for both follow-up and survey strategies. The collaboration between the active observers and processing experts was established. Observations are performed based on the provided schedule in order to find the SST tracklets. Those are further sent to the ESA Expert Centre for further analysis.

The SST functionality is being finalized for the ESA Test-Bed Telescope in Cebreros, Spain. Czech industry and academy are collaborating on the control and processing software of the robotic telescope. The same functionality is being prepared for the second telescope that is going to be built in Chile.

Near Earth Objects (NEO)

- NEO observations & information provision;
- NEO mitigation support (incl. fireball monitoring);
- Advanced NEO spectroscopy technologies;
- Research and development in the field of special optics, optoelectronics systems and optical measurement methods, robotisation and remote control of telescopes;
- NEO Software development (tasking and scheduling of telescopes, long-term archiving and analysation of NEO data).

ESA is in the process of building the NEO Survey Telescope, which will scan the sky in order to discover new asteroids. The Czech Republic is involved in the development of special optic components and in the data processing part where the experience from the Test-Bed Telescope is being used.

The capabilities of Czech academia also includes operations, and autonomy analysis as well as with on-board software development, planetary geology research, spectroscopy, optical navigation, internal composition and structure analysis, data processing and autonomous navigation algorithms. However, these capabilities are mostly at low TRL level to be readily embarked to a mission and therefore must be further developed.

Space Science and Exploration

Specific area of upstream are the scientific instruments. The direct participation of the Czech research institutions include:

- Langmuir probes and thermal plasma measurement units for Proba-2 satellite;
- Low frequency wave receiver and power supply for the radio and plasma waves instrument for JUICE;
- Space radiation detectors for Proba-V mission and compact radiation detectors for real time dose monitoring in the living modules of the ISS;
- Three micro-accelerometers for Swarm satellites precisely measuring movement caused by the non-gravitational forces impacting the spacecraft trajectory;
- Single photon laser detector instrument for the ELT experiment comparing the atomic clock time measurement offset between clocks on ISS and on the Earth by laser pulses;
- Optical elements and the mechanism of the front door assembly for the coronagraph ASPIICS at Proba-3 formation flying mission;
- Acousto-optical IR rapidly tuneable filter based on Calomel monocrystal;
- X-ray scintillation detectors developed from enriched garnets monocrystals;
- Experiments for evaluation of short- and long-term radiation effects on algae and cyanobacteria;
- Power supply and distribution unit for X-Ray spectrometer-telescope STIX for ESA Solar Orbiter mission;
- Optical assembly including high-specification mirrors for the coronagraph on ESA Solar Orbiter mission;
- Plasma wave instrument units for Solar Orbiter mission;
- Proton detector sub-units for Solar Orbiter mission;
- High frequency wave analyser and electron analyser for TARANIS microsatellite;
- Wave analyser module for the Exomars 2020 surface platform;
- Scientific data simulations aiming to identify desired parameters for X-ray detector for ATHENA satellite;
- Application of high-power lasers for support of space missions;
- High-resolution mass spectrometry as extension of French CosmOrbitrap consortium for future exploration mission.

As a rule, scale and focus of national contributions to such scientific instruments or their parts is negotiated by the academia, which is directly involved in the respective international scientific consortia. Technical implementations are then realized in a close collaboration with national industrial partners, which often take the leadership of the development.

2.2.3.2 Midstream

Midstream segment consists of components and technologies for support space missions' utilization. From this point of view in some cases, it ensures bridging between upstream and downstream. The midstream segment is related mainly to data pre-processing, storage, archiving and distribution. As a midstream could be counted also all the infrastructure related on operation of space segment, that means uplink and downlink stations, communication networks etc.

There are the following capacities in midstream in the Czech Republic:

- Building of whole mission operation centres, uplink and downlink communication antennas and related infrastructure;
- Building and operation of data centres and archives, computational and dissemination platforms for EO or any other kind of space data;
- Growing capacities in big data computing, cloud computing, development of AI as a tool for EO data processing;
- Development of Internet of Things (IoT) networks, which could serves for calibration and validation of EO data;

- Building and operation of GNSS permanent reference station networks (excl. manufacturing of the GNSS receivers / antennas),
- Developing software suites for real time monitoring performance of GNSS, across all international constellations and over extended periods, showing relative trends among different constellation developments.

2.2.3.3 Downstream

Downstream segment refers to industrial activities, which use the space infrastructure and space based data to provide tools and services for general users. The potential market for this area is very difficult to estimate.

To be successful in the downstream segment some fundamental ingredients are necessary: a) excellent software expertise, b) very close consultation with the potential customers, not only to define precisely what will be delivered in the service or application but, also the costs and possible income from those customers. However before the use of a technology becomes a commodity, a deep or detailed knowledge of the space systems or instruments of which data are used is also necessary. Before the use of navigation technologies became a commodity these entities were early adopters with technology knowledge close to the space segment. This has allowed them, not only to be early adopters, but also to become dominant in the market of navigation applications and services.

The downstream segment is harder to directly target through ESA activities since the EU funds, by more than an order of magnitude, support services and applications development related to the use of Galileo and Copernicus.

There is a significant number of companies with technology potential to develop space oriented focus – both in upstream and downstream. However, as pointed out above, the upstream work is constrained by the Czech contribution to ESA, and hence any effective significant growth has to be led by corresponding increase in the contribution to ESA.

On the other hand, while the downstream business may not have this direct constraint, it is much harder to break into because of the already established (developed before the Czech Republic became an ESA Member) European players.

At the same time, ESA fully funds preparatory activities in this segment and co-funds downstream activities that should be better exploited.

Earth Observation

EO downstream capacities and capabilities in the Czech Republic in general are especially the following:

- EO data processing – multispectral, hyperspectral and SAR data. Development of new EO data based products (incl. integrated applications) based on EO data, e.g. SAR ground motion and infrastructure monitoring, SAR, multispectral and hyperspectral data for environment applications, agriculture, land use, land cover, monitoring or natural disasters, monitoring and modelling of atmosphere etc.;
- Laser scanning data use / products development;
- Integration of EO data based information into GIS and customers systems, services for both midstream and end-users;
- scientific EO data processing, e.g. GOCE, SMOS, SWARM and others;
- machine learning and Artificial Intelligence for EO data processing; blockchain based services / technologies for EO;
- Spectroscopy, spectrometry, SAR interferometry, gravimetry (mainly academia);
- Cal/Val;
- New processing algorithms development.

Navigation, SatCom and integrated applications

Number of companies develop applications, which use GNSS as the primary source of position, navigation and timing. Examples exist in many domains of national economy, ranging from the traditional domains of transportation and logistics, fleet management, intelligent transport systems, e-Call, drones, environmental protection, civil engineering and precise agriculture and forestry to personal tracking and health monitoring, location based services, sports, geo-marketing, media and entertainment. A newly emerging application domain in Czech Republic is autonomous mobility, especially the field of automated and connected cars. Although the GNSS location provides only one piece into the automated driving puzzle, it is an important one. GPS time has been widely used in Czech Republic by banks, electricity grids and telecom operators, to synchronise their networks. This will most likely not change, but solutions integrating diverse timing sources (GNSS multi-constellation timing receivers, Loran) are expected. Many of the applications mentioned above are critically important for national economy, for general stability of the state and safety of people. Therefore, much attention is necessary to make those applications properly secured, robust and resistant to intentional and unintentional interference. Another novel application integrating GNSS with Earth or sky observations and SatCom is the domain of high altitude platforms (HAPs). Czech industry is pioneering this domain with some potentially very interesting applications ahead. The traditional GNSS localization has been widely used by official authorities for crew management of police and rescue forces in crisis and emergencies. Another widespread application domain is precision agriculture by automated tractors and harvesting vehicles, as well as the related area of insurance for farmers. Regarding purely SatCom applications, the market in the Czech Republic is very small, due to usually very good terrestrial and mobile communication coverage. The only exception is satellite TV, which is a service traditionally used by households usually in remote areas, which are disconnected from the cable TV or optical internet network. Overall, the GNSS and integrated applications is a very promising area, where many potential new application developers and users coexist, but they are still not aware of all the possibilities, which space systems offer.

3 VISION AND OBJECTIVES

3.1 VISION

The vision of the Czech Republic for the upcoming period builds upon the two previous strategies – 2010 NKP and 2014 NKP, i.e.:

- To have an international image of industrial and scientific excellence;
- To be a high value-added economy;
- To be competitive and innovative;
- To be capable of absorbing and retaining the intellectual capital it creates;
- To be an example of an excellent complementarity and cooperation between its industrial and academic tissues;
- To be an expert user of space resources and infrastructure in operational products and services (EO, navigation, etc.).

3.2 OBJECTIVES

3.2.1 CZECH SPACE CAPACITY AND CAPABILITY BUILDING TO INCREASE EXCELLENCE AND COMPETITIVENESS

Space exploration must not be considered as an end in itself but as an economic instrument for development and innovation. Due to objective, largely economic, reasons, the Czech Republic cannot undertake all space activities. Therefore, it will aim its support mainly at those activities or programmes with the potential to bring the largest added value to the Czech Republic, its national economy and its physical and legal entities from the strategic, economic and security point of view. Generally, those space activities or programmes that will lead to higher potential benefits across several areas of the space activities will be favoured.

The existing space related eco-system around Czech space industry is expected to bring multiple benefits to the Czech Republic. For instance, some of the most tangible benefits that need to be considered are:

- Employment of high educated people in order to retain talents in the Czech Republic;
- Creation of synergy between SMEs and large industry;
- The natural strengthening of cooperation between industry and academia (universities and the institutes of CAS);
- Creation of business incubators to exploit the high potential for start-up business;
- Commercialization and manufacturing of space products in Czech Republic;
- Revenue from intellectual property licensing.

Another important benefit from this eco-system is the impact on Czech academia. The eco-system will provide a unique opportunity to Czech academia to further develop its research agenda, and open new PhD positions in order to address the new issues related to space systems.

Thanks to the tremendous efforts made by all entities over the years, the Czech Republic managed to build a critical mass of space capacities and capabilities of its industry and academia and it can partially redesign its strategy now. It does not mean at all that the Czech Republic should stop in further development of its space capacities and capabilities. Just on the contrary, the Czech Republic has to accelerate all necessary steps to further help the industry and academia to mature, stabilise and promote their existing capacities and capacities and also create and master new ones, especially those which logically complement the existing ones. The Czech Republic also should attract new Czech industrial players to engage in space activities to develop new space technologies, technologies for New Space and also and downstream applications, i.e. new space capacities and capabilities, possibly utilizing and capitalizing on their own originally non-space technologies in space. At the same time space industry and academia in cooperation with various other industries should be motivated to take steps to use technologies developed for space down-to-earth to improve their conventional businesses (through automation, engineering, chemistry, etc. to evolve aviation, automotive, energy or defence sectors).

The main change coming with the fact that the critical mass of space capacities and capabilities of Czech industry and academia has been created is that we can now define more complex and ambitious projects. Such projects (hereinafter referred to as "ambitious projects") should help the Czech Republic to develop its space capacities and capabilities much faster than moving ahead as before. Such objectives are riskier but still feasible. The return of investment of complex and riskier undertakings may come later than usual, but if successful, they can bring the Czech Republic huge benefits. Such undertakings will also make the Czech Republic and its entities more visible.

3.2.1.1 Specific Objectives

Specific objectives will be implemented as principles for support of projects funded within available tools (see Chapter 4) and further supported by other measures (see Chapter 5).

A) <u>To be compliant with market trends and needs</u>

The Czech Republic should not support development of industrial capacities and capabilities which have very low chance to be successful on European or global market. When evaluating whether or not to grant the support to the project proposals, the great emphasis should be laid on compliance with technology and market trends, competitive advantages and orientation on niches.

The Czech Republic should also support scientific research of planned missions and development of scientific instruments for space science missions to enable Czech academia teams to pursue their own projects proving their scientific excellence worldwide.

B) <u>To be innovative</u>

There is a need for innovative new products and systems that will allow Czech industry to achieve decisive benefits from their participation in space activities. Long-term success can only be achieved through the implementation of the newly developed capabilities that will require consolidation into economically sustainable products. This will further help the whole Czech space industry further strengthen its excellent international reputation and to operate in areas capable of bringing high added value and not only to create but also retain intellectual capital.

C) <u>To be disruptive</u>

Disruptiveness can concern innovations of processes and technologies or concepts and approaches. Disruptiveness as well as innovation cannot be planned or forced out, but we can motivate and stimulate industry and academia or just people to think disruptively and come with disruptive solutions. As we can see, especially overseas, non-space actors are coming with new concepts how to use space. In addition, in space domain itself, there is a lot of room for completely new concepts and approaches which may have rapid and major effect on technologies that exist now.

The more revolutionary projects focusing on innovations of processes and technologies or new concepts and approaches the riskier they can be. However, such projects have to be still realistic and feasible. The risk should be identified and adequately controlled and mitigated.

D) <u>To be excellent</u>

In accordance with the European research prerequisites, also the Czech Republic aims to reinforce and extend the excellence of its science base and to consolidate the overall research environment in order to make the Czech Republic's research and innovation system more competitive on a European and global scale. National and international cooperation should be a means to achieve this objective.

E) <u>To create, protect and exploit Intellectual Property Rights</u>

Since the Czech Republic has a serious deficit in intellectual property rights (IPR) exploitation, the great emphasis should be laid on this area. For the further development of space activities in the Czech Republic, it is very important to improve by all means all possible ways how to ensure the protection of IPR.

All activities under NSP should consider the protection of the IPR and the exploitation of these rights.

All R&D activities funded with public funds should aim towards developing and protecting their own IPR and the exploitation of these rights should take place in the Czech Republic. This does not exclude that, for the purpose acquisition of know-how, fully licensed products may be manufactured and/or exploited in the Czech Republic.

It does not exclude funding of activities where ESA retains the ownership of the IPR for operational or continuity reasons like maintenance, upgrade or development of the systems developed, as they ensure a competitive advantage for participating academia or industry.

For both low and high TRL technologies, the role of IPR is crucial to ensure the property of the technology at the base of future products, applications and services that can bring benefits across the Czech economy.

The possession of technology, however, is not the only condition necessary to achieve these benefits. It is also necessary to ensure, to the maximum possible, that these technologies are exploited in the Czech Republic. The collaboration or teaming of academia with Czech industry is a very important factor, especially in the middle-low TRL, in this process. For this reason projects that encourage this collaboration, in the respect of their roles, should be encouraged.

F) <u>To increase cooperation between academia and industry respecting their natural roles</u>

To ensure that the natural missions of academia and industry are exploited to maximise the economic benefit across society, also in terms of return-on-investment of the public money, and ensure economic sustainability, it is important to discuss and define their roles.

It cannot be over-emphasised that both communities are highly important in the space sector as in other economic sectors of activity and depend on each other. At the same time, it should not be forgotten that the funding of academia activities constitutes less than a tenth of the ESA budget. Most of the funding for academia comes from national research budgets, such that for industry, these are hard to obtain.

Roles of industry and academia can be also demonstrated using technology readiness levels (TRL).

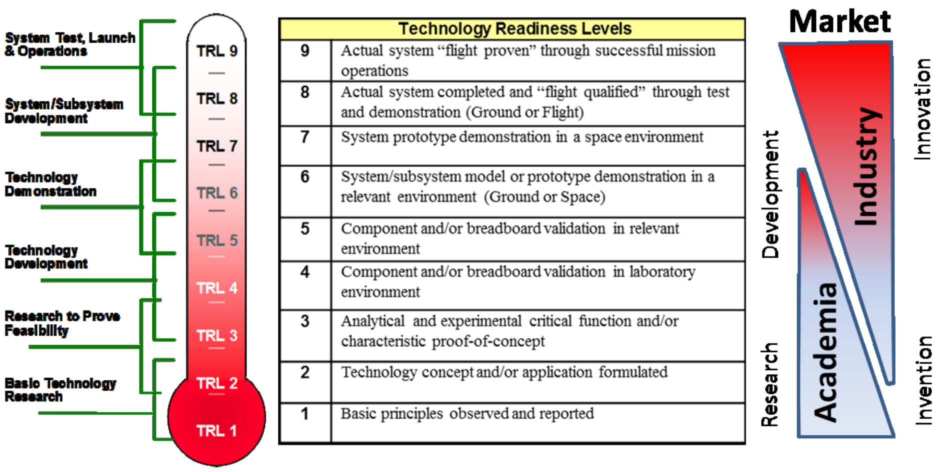

Figure 4: Technological Readiness Levels in the context of the roles of academia and industry. Source: ESA

The TRL concept was developed originally for space that describes the status of development of a technology in a scale from 1 to 9. TRL 1 is the lowest level and is when basic principles were observed and reported. TRL 9 is when the technology associated with the system was successfully used in a space mission. Significant TRL is 6 corresponding to the demonstration of a prototype using the relevant technology in a representative environment while TRL 3 is when the technology proof-of-concept was analytically or experimentally confirmed.

Technology readiness (or lack of it) is one of the major sources of cost over-runs or delays in space missions. The reason for this is directly related to the risks associated with having the systems on a satellite, that use a particular technology, ready within cost and in time for the launch. For this reason, space agencies use TRL for all the technologies that may be necessary for a space mission.

As can be understood from the TRL, academia plays a fundamental role up to TRL 4. Around this level, the technology is more efficiently implemented in industry with decreasing level of involvement of academia with increasing TRL. It should be noted that while the TRL shown in Figure 4 are pertinent to space activities, the same concept can be (and is) applied to many other sectors of economic activity that involve R&D targeting the market and innovation.

G) To create synergies among companies and between SMEs and large industry

The economic eco-system in the Czech Republic can be further stabilised not only if there is a high standard of cooperation between industry and academia using their natural roles but also if there is a high level of cooperation among companies themselves completing individual value chains. Interconnected value chain between SMEs and large industry needs to be created as well. Large companies may stay more operational if they do not absorb all competences and implement some activities in external cooperation.

Companies, if they do not provide their products or services to end-users only, should cooperate with other companies, nationally or internationally, to develop products and services to be further put to the market. The bigger subsystems are developed and offered and the more related processes are mastered, the bigger chance is to succeed on the market, win new contracts, participate in further developments and stay in supply chains.

Large companies may stay more innovative if SMEs supply them with new ideas. Unlike SMEs they can use bigger funding capacity to further explore such ideas.

H) To maximise Return-on-Investment

The need to retain and absorb the intellectual capital that is created in the Czech Republic is an essential requirement to ensure the "return-on-investment".

Assuming that, in some special cases, academia is able to pursue a technology up to TRL 6 or above, then the problem is one of maximizing the return on investment to develop the technology.

In these cases, the difficulty is in transforming the technology into a product and in retaining the scientists or engineers that performed R&D in academia. The return-on-investment in this case is very small, translating into having the personnel employed during the course of the activity and little else.

An exception is the development of scientific payloads where institutes of the CAS are the end users of the product and often participate in its development, together with industrial partners, from conception to operational phase. In such cases, when permanent academic staff is involved in the development, the know-how and continuity can be preserved both by the academic and industrial partners.

In an industrial setting it is easier to achieve a product that can be exploited commercially, because market considerations are taken into account and influences design, manufacturing and production. In addition in industry, it is usually easier to retain the scientists or engineers that performed R&D. This is very often what renders a development with a high return-on-investment because the market for the new product becomes economically sustainable.

In order for Czech entities to actively participate in the development of new technologies and their ultimate implementation/application, it is desirable that they participate in relevant projects from their initial stage when directions and goals are being defined.

When supporting project proposals to be implemented, special attention has to be paid to expected impacts of the projects, such as ratio of private investments, creation of new jobs, expected revenues both in space and non-space sector, or incomes to public budgets. However, there will always be cases of important and worthwhile projects where expected revenue is not clear or is far down the road.

I) To increase ratio of private investments

ESA funds majority of its technological activities by 100 %. It reflects the fact that space projects are on the top of innovation and are usually very risky. In certain domains of space activities which are becoming more commercial, especially in telecommunication, industry is increasingly able to take a part of the risk and co-fund activities. ESA has been accommodating its programmes accordingly.

The Czech Republic's space industry is still a newcomer in space sector being compared with its partners and competitors in Europe. The large European space industry is mainly a product of long-lasting massive investments of some states. The capacities and capabilities of large European space industry cannot be ignored in development of the Czech Republic's space industry.

To approach and/or catch up with such capacities and capabilities which are still being further developed in the course of time, special measures to accelerate the Czech space industry and academia capacity and capability building must be implemented. As one of such measures, the highest possible ratio of public investment allowed by individual schemes needs to be used. Gradually, hand in hand with creating more robust base of space industry in the Czech Republic the ratio of public investments has to decrease in close to market activities. Otherwise space industry may become dependent on public funding and sound development of space sector may get deformed in the Czech Republic.

Co-funding scheme has to be balanced to be still able to motivate industry to take over risks in technologically very demanding projects.

Concerning downstream, ESA fully funds preparatory activities and co-funds demonstrations activities that should be later exploited.

J) To stimulate and accelerate technology and knowledge transfer

To maximise the return on investment, the Czech Republic also aims at creating an environment for knowledge transfer acquired through space activities including results from research, technology development and services into other fields. The Czech Republic also focuses on establishing an environment for knowledge transfer from other sectors to the space sector.

3.2.1.2 Priority Areas for Intervention

A) Space Technologies

This area includes technologies for:

- Spacecrafts to be used for a variety of purposes, including satellite telecommunications, Earth observation and meteorology, satellite navigation, space exploration including deep space missions (i.e. Moon and Mars missions and beyond), space resources prospection and utilisation, Space Safety and Security, transportation of humans and cargo including launchers or sub-orbital spaceflights and in part HAPs;
- Ground segment to operate such spacecrafts and in part ground-based activities related to space missions.

Possible public support to develop a specific technology depends primarily on benefits such technology may bring to Czech economy. Special emphasis needs to be put on building integration capacities and capabilities in the Czech Republic to be able to absorb larger activities and increase added value of space activities for Czech economy.

B) Satellite Downstream Applications

Satellite downstream application, based on satellite telecommunications, satellite navigation and Earth observation, using especially data from satellite systems or using satellites as a means influence more and more everyday life of our society. This area gives immense opportunities to come with new ideas with relatively short way to market when encouraged and supported well.

C) Scientific Payload

This area should prove effective cooperation between academia and industry in projects primarily focused on fulfilling scientific needs. Such projects could also help industry to demonstrate technologies or master integration skills.

Scientific payload projects are excellent tools to increase international scientific cooperation and at the end of the specific mission to provide unique scientific data for further research. When negotiating and supporting participation in scientific payload project, special emphasis has to be put on the following aspects:

- Czech academia should play significant roles in respective international consortia;
- Czech entities should be responsible for development of high-tech components of the payload to increase added value of such activity for the Czech economy.

D) Ambitious Projects

There are three main reasons why implement ambitious projects (missions):

- To give the Czech Republic the real strategic goals in space;

- To speed up development of Czech space capacities and capabilities;
- To increase overall visibility of the Czech Republic.

The ambitious projects should be implemented by higher number of cooperating entities from Czech industry and academia. The programmatic content of such missions should be defined by cooperating entities, unless such mission is focused on meeting requirements of state users. Further, the programmatic content should be reviewed by a committee of experts nominated by Czech ministries. The Specific Objectives defined in Chapter 3.2.1.1 should be respected as much as possible.

The selection of the mission should follow prescribed procedures according to the funding scheme to be used.

The ambitious project should bring benefits both to industry and academia and by their means to Czech Republic and its citizens. Preferred cases will be as follows:

- **Technology demonstration mission.** This ambitious project should include the following elements:
  - Czech industry acquires and/or masters its integration capabilities;
  - Czech industry demonstrates its technologies/services to gain space heritage faster to accelerate their way to customers and market;
  - Czech companies themselves demonstrate their effective and efficient cooperation complementing each other and create value chain;
  - Czech companies and academia demonstrate their effective and efficient cooperation using their natural roles;
  - Technologies developed for the mission, provided services and/or capabilities acquired during the mission will help to develop other industrial sectors or can be put or used to non-space markets.
- **Technological/scientific mission focused on disruptive activities or perspective activities with growing attention and interest like utilisation of space resources, space debris removal, in-orbit servicing, planetary defence, space weather etc.** This ambitious project should include the following elements:
  - The Czech Republic increases its reputation and visibility in global scale and awakens an interest of main players in further international cooperation;
  - Czech industry acquires and/or masters its integration capabilities;
  - Czech academia demonstrates its scientific excellence and increase its competitiveness vis-à-vis foreign counterparts;
  - The Czech Republic strongly demonstrates broader application of capacities and capabilities of its industry and academia, including extended use of their technologies and services developed so far;
  - Czech companies themselves demonstrate their effective and efficient cooperation complementing each other and create value chain;
  - Czech companies and academia demonstrate their effective and efficient cooperation using their natural roles.
- **Technological/application mission focused on meeting requirements of state users**. This ambitious project should include the following elements:
  - The Czech Republic increases its reputation and visibility in global scale and depending on the concrete focus of the mission may increase its strategic value (in military, intelligence, crisis management etc.);
  - Czech industry acquires and/or masters its integration capabilities;
  - The Czech Republic strongly demonstrates broader application of capacities and capabilities of its industry and academia, including extended use of their technologies and services developed so far;
  - Czech companies themselves demonstrate their effective and efficient cooperation complementing each other and create value chain;
  - Czech companies and academia demonstrate their effective and efficient cooperation using their natural roles;

Other states and/or foreign partners could be invited as potential primary end-users or to cooperate in development of such a mission.

E) <u>Support Infrastructure</u>

In achieving goals of points A) to D) the Support Infrastructure plays an irreplaceable role. Developing sufficient capabilities and capacities to verify, validate and test the developed solutions in the Czech Republic allow industry and academia to efficiently exploit their innovative potential.

Such development of support infrastructure shall be based on analysis of programmes and projects in which the Czech industry and academia will be participating in the near future.

3.2.2 Active Position in International Relations to Increase Visibility of the Czech Republic

The Czech Republic is a member state of various international organizations. Its visibility in the international organizations differs from one to the other especially depending on its interest in particular matters, capacities and capabilities of its representatives and their activeness, positive approach and added value, its funding capacity, level of solidarity, fairness and openness for cooperation and implementing common goals or capacities and capabilities of its industry and academia. All these aspects have to be taken into account to find a balance between pure activeness and real interest supported by funding capacity and capacity and capability of industry and academia.

The Czech Republic should effectively participate in international organizations, maximize benefits from its membership and be a valuable partner for other member states on the other side.

The Czech Republic should try by all means, both formal and informal, to contribute to searching for generally acceptable solutions to promote international cooperation and support efforts to find international consensus and further development of space activities especially in areas where the actual situation is blocked, e.g. utilisation of space resources, planetary defence, etc.

Besides, the visibility of the Czech Republic will increase when its space activities implemented by its industry and academia will excel by innovativeness, disruptiveness or benefits for economy, science and society.

Concerning bilateral cooperation, the Czech Republic should continue in building bilateral relations with other states. The countries to cooperate with range from the major space powers to the smaller participants and to those which are only making the first small steps. The international cooperation should be promoted by state, industry and academia. I should be noted that it may take sometimes years having communications before the relationship matures into a joint project.

The Czech Republic will also further strengthen and develop its relation with GSA and then with EUSPA, seating in Prague. The main objective is to intensify cooperation with GSA and then with EUSPA at bilateral level and ensure suitable conditions for its activities.

4 Tools to Implement the National Space Plan

Space activities often face misunderstanding and misinterpretation concerning what they represent and who are their stakeholders and from where they are coming. Space activities are about science as well as about business. They are close to people's concerns and more and more influence our everyday lives. They are also generator of fascination and inspiration through exploration and science.

Decision makers as well as general public need to understand that space activities are mostly at the real top of innovation chain. If the state economy is supposed to prosper and the public welfare is supposed to grow, the high added value activities have to outweigh the low cost activities. Added value of space activities belongs to the highest ones.

Even smaller states have number of opportunities to show their scientific excellence and use their industrial potential to be innovative and address market, especially the niche market. Small states may be disruptive and help to change fixed ideas. They can also contribute to the common endeavours.

Since space activities are very complex, all possible stakeholders from general public to entrepreneurs and scientists must be addressed. Special attention needs to be paid also to education and training as an irreplaceable tool to prepare new Czech capacities and capabilities.

4.1 Awareness Raising, Education and Training

4.1.1 Awareness Raising

In order to ensure a high level of awareness, knowledge of the professional community concerning the importance of space activities, their benefits for individuals and entire society and respective opportunities, there is a need for close collaboration, involvement of various player both of public and private sector and their one way approach. Only if they understand the importance of space activities for Czech Republic's economy and citizens, we can expect an increase of interest among parents to educate their children in this domain or among young professionals to start their carriers in space business etc. In this respect, the increased interest in the society will require more educational and training opportunities, new ideas, projects and jobs. All these elements must be encouraged in the Czech Republic in cooperation of relevant entities.

4.1.1.1 General Public – Adults

The official space web portal of the Czech Republic managed by the MD (Czech Space Portal)[4] and webpages of other entities have been addressing the general public with a wide range of information concerning both space activities of the Czech Republic and space activities in general (e.g. participation in ESA programmes, industry and student opportunities, interesting facts about astronautics, aerospace, intelligent transport systems, etc.). Space activities of the institutes of the CAS are also addressed by the public outreach events organized in the frame of the Strategy AV21 programme "Space for the mankind".[5]

The awareness raising actions undertaken for general public can be summarized as follows: the distribution of relevant information through information portals and related social networks, publications (brochures, newsletters, informative video spots etc.), media coverage of some highlights (e.g. Czech Space Week), media coverage of Czech participation in projects overlapping to space activities, presentations of space activities within the national events for the general public, etc.

4.1.1.2 General Public – Children & Youth

The objectives of awareness raising in the area of space activities towards children and youth are to encourage their interest in further studies of subjects and disciplines relevant to space sector and motivate young generation to pursue careers in the fields relevant to space activities.

The awareness raising activities carried out in the area of space activities towards children and youth can be summarized as follows: the distribution of relevant information through the specific web portal sections of the Czech Space Portal, social networks, publications (sheets, paper cut-outs, informative

[4] http://www.czechspaceportal.cz/.

[5] http://www.vesmirprolidstvo.cz/.

video spots, etc.), presentations of space activities for youth within the national events for the general public, specialized courses and after-school activities arranged by observatories and planetariums, etc.

4.1.1.3 Professional Public

The majority of the activities already carried out is aimed at creating positive environment for the Czech industry and academia to be able to easily learn about actual or prospective possibilities and opportunities. They should help them to establish, develop and intensify their mutual cooperation and/or the cooperation with foreign entities, especially industrial ones, to accelerate grow of their capabilities and ensure their competitiveness. The activities are more or less focused on the relatively narrow group of specialists.

The awareness actions undertaken towards the professional public can be summarized as follows: distribution of relevant information through information portals and social networks, organization of many professional and technical seminars/workshops, space industry days, networking events, user forums (Galileo User Forum, Copernicus User Forum), publishing activities (catalogues, brochures, information materials), media coverage of Czech participation in the international projects overlapping to the space activities, support of Czech participation in international competitions with overlap in space activities, as well as the organization of regional rounds of these competitions (e.g. Galileo Masters), presentations of space activities within the national events for the professional public, etc. Seminars and conferences for professional public are also organized in the frame of the CAS Strategy AV21 programme "Space for the mankind".

4.1.2 Education and Training

As in the whole EU there is a shortage of skilled technically oriented graduates in the Czech Republic in all high-tech sectors. The expanding space sector needs a sustainable supply of graduates and technicians with appropriate skills.

Space has a special role in using its exciting science and engineering to inspire young people to take STEM subjects at schools and universities.

4.1.2.1 Primary, Secondary and High Schools

Space related education at primary, secondary and high schools is based on teaching STEM subjects. Even if the Czech Republic has a quality educational system, the area of polytechnic education has been underestimated for a long time. A sophisticated STEM system (Science, Technology, Engineering and Mathematics) is still missing. This area is one of the key competencies within the new curriculum concept from nursery to secondary schools.

The MD created the European Space Education Resource Office (ESERO) in the Czech Republic in 2014 (https://esero.sciencein.cz/) to carry out supporting activities to exploit the inspirational effect of space in delivering education and capturing and shaping the skills and imagination of the next generation of innovators and scientists.

4.1.2.2 Universities and Ph.D. Studies

Czech technical universities prepare their graduates to work in the mechanical and electrical/electronic engineering fields of aerospace. Namely, they offer graduate courses on aircraft structures and design, flight measurement systems, cybernetics, robotics, optical systems, communication systems including satellite telemetry and related technology. Respective departments of natural sciences give more scientific oriented courses focused on space science, astronomy, atmospheric and ionospheric research as well as on biology, geology, hydrology and geodesy.

In space technology, the first advanced education programme available in the Czech Republic has been the European international multi-disciplinary programme "SpaceMaster".

There are also two another master programmes, namely "Aircraft and Space Systems/Aerospace Systems" (accredited in 2010) and "Aeronautics and Astronautics" (accredited in 2016).

There are also opportunities to study at foreign universities (i.e. International Space University, Toulouse III – Université Paul Sabatier, TU Delft, etc.).

The Institute of International Relations (IIR) in Prague established the Centre of Technology Governance in May 2019 with particular focus on space activities. Its planned activities beyond the natural role of educating and advising the policy and decision makers and exploring possible opportunities in multilateral cooperation includes Ph.D. students supervision.

4.1.2.3 Young Professionals & Life-long Education and Training

The opportunities related to the "purely" space-oriented education for young professionals can be found only abroad. Two internship frameworks for young professionals have been recently utilised by the Czech graduates and Ph.D. students, namely ESA's Young Graduate Trainee (YGT) programme and student programmes (second stage of tertiary education) of the International Space University. Another opportunity can be seen in the use of the ESA´s Postdoctoral Research Fellowship Programme which aims to offers young professionals the possibility of carrying out research in a variety of disciplines related to space science, space applications or space technology.

The CAS offers on competitive basis a funding scheme for 2-year postdoctoral position in its institutes. This scheme is also currently used for space-oriented subjects.

Occasionally, MD together with partners organizes life-long educational space-oriented vocational training courses, e.g. on how to write a proposal, IPR, ECSS Standards, etc.

4.2 COMPETITIONS

To stimulate an interest in space activities and to identify and further support innovative ideas and solutions, MD, CzechInvest or ESERO organize national challenges of number of international competitions.

Galileo Masters is an international competition for projects with innovative ideas focused on the exploitation of the GNSS. MD is the regional organizer of the competition and together with its regional partners organizes the Czech Republic Challenge on yearly basis.

Copernicus Masters is an international competition that awards prizes to innovative solutionsand ideas for business and society based on Earth observation data. MD is a regional associate of the competition and together with its partners promotes it in the Czech Republic.

There are also other competitions giving opportunities to Czech entities, students, young people etc. to break through with their ideas. E. g. CzechInvest within ESA funded EO ClimLab project organizes EOVation Masters to support new ideas how to use Earth observation data and ESERO organizes CanSat Czech Republic, a regional challenge of international design-build-launch competition.

ESA also organizes Space Exploration Masters in which annually awards the best business ideas providing concrete business opportunities to strengthen the benefits of Space Exploration to society with products and services.

MD together with MA promotes Farming by Satellites competition in the Czech Republic on how we use satellite technologies to improve agriculture and reduce environmental impact. The competition is organized by GSA and other partners.

4.3 INCUBATION AND TECHNOLOGY TRANSFER

The Czech Republic joined the European-wide ESA BIC network in 2016 by establishing ESA BIC Prague. In 2018, ESA BIC Prague branch in Brno was open. The operator of ESA BIC Prague is CzechInvest. MD, MPO, Capital City of Prague, South Moravian Region and South Moravian Innovation Centrum (JIC) are its main partners. The ESA BIC provides financial, technical and business support with aim to turn innovative business concepts, using space technologies into successful businesses. The actual plan is to incubate 25 companies in Prague and 9 companies in Brno by 2021. ESA BIC Prague has already had its few alumni and its success rate is 100 % so far.

The Czech Republic also joined the ESA Technology Transfer Network in 2015. The network consists of brokers across Europe who are working to identify novel uses for technology that has been developed as part of the ESA space programme. They are also interested in identifying technologies in other sectors that could benefit the exploration and utilisation of Space. The operator of ESA Technology Transfer Broker in the Czech Republic is the Technology Centre of CAS.

As from 2020 the ESA technology transfer and incubation activities will become part of the ARTES BASS (Business Applications-Space Solutions programme, formerly known as IAP), connected to even broader supporting network with ESA member states engaged through Ambassador Platforms, access to venture capital of private investors, banks and innovation networks for supporting entrepreneurs and SMEs; all of that combined with a focused and united marketing and outreach approach, while connecting the space and non-space industry. This network support is called the ESA Innovation Partners Network and can be transversal to all directorates of ESA.

4.4 PROJECT SUPPORT TOOLS

The space technologies require a multi-year budget approach not only because of the length that any space mission requires but also because any discontinuity in the availability of resources will lead to a loss of the expertise, competence and know-how previously created – especially in industry. The space applications usually do not require the same approach as space technologies but a specific tool would very much help to support further development of this rapidly growing sector.

4.4.1 NATIONAL LEVEL

Nowadays, there is no specific national tool in the Czech Republic, which would be used directly to support space activities. If it existed, such a tool could be a main tool for implementation of the NSP. It also would help to interconnect in suitable way the existing general project support tools and coordinate their use in favour of the area of space activities.

In general, availability of national tools for funding of some activities like e.g. preparatory activities, scientific payload to various missions, educational and training activities, etc. could influence the preparedness of Czech industry and academia to participate in European or international programmes and help them to become more competitive. They also can help the Czech capacities and capabilities to be more sustainable in a long term.

Discussions on establishment of such a tool in a form of the national space programme led in decision to initiate the establishment of the C3PFP. The C3PFP represents the third pillar of possible cooperation with ESA. ESA manages the technical and contractual aspects of the C3PFP whilst the Czech Republic takes programmatic and financial decisions.

Even if implemented by ESA, this C3PFP can to certain extent represent the national space programme. It is however tailored rather to speed up the development of the technological level of Czech Industry and academia to be more competitive at the European or global markets helping them to overcome some obstacles, than to implement ambitious Czech space missions or participation of the Czech Republic in international missions. The outcomes of the C3PFP can be further developed in ESA programmes and activities, Horizon 2020 or used on institutional or commercial market.

The C3PFP also opens a possibility to support training schemes.

Since the Czech Republic has full control over the budget of the PRODEX programme at the national level, the PRODEX programme can be also considered as a tool partially substituting the national space programme nowadays. PRODEX programme is one of ESA optional programmes that provides resources for the development of scientific instruments or experiments, proposed by institutes, universities and industry in the Czech Republic. Usually these are selected by ESA for one of its own programmes in the various fields of space research (astronomy, astrophysics, planetary science, microgravity, Earth observation, etc.), however the PRODEX programme can also be used for funding of such activities for non-ESA missions. The Czech Republic is responsible for evaluation and selection of projects to be financially supported from the PRODEX programme whilst ESA manages the technical and contractual aspects of such projects. PRODEX programme is further discussed in Chapter 4.4.2.1.

Other functions of possible overarching national space programme including interconnection of the existing general supportive tools and coordination of their use in favour of the area of space activities are not implemented so far and remain for further consideration.

In the Czech Republic there is also a number of general tools which may be used to support space activities and related areas:

- **Operational programmes** as part of the European Structural and Investment Funds with their support schemes in various domains aiming to gradually reduce disparities between individual regions of the EU Member States, thus improving the everyday lives of all Europeans. For implementation of NSP are relevant especially the following operational programmes:
  - Competitiveness (MPO);
  - Research, Development and Education (MŠMT);
  - Transport (MD);
  - Environment (MŽP);
  - Employment (Ministry of Labour and Social Affairs);
  - Integrated Regional Operational Programme (MMR);
  - Prague – Growth Pole of the Czech Republic (Prague).

  Space activities are well mentioned in the National Research and Innovation Strategy for Smart Specialization, which is the condition for their support in the operational programmes. On the other side, the support of space activities and related areas from operational programmes is rather random than systematic.
- **Support of industry** to create attractive conditions for Czech and foreign investors and encourage them to maintain long-term business activities and to reinvest in the Czech economy.
- **R&D and innovations**: the support is based on the Revised National Research, Development and Innovation Policy of the Czech Republic in 2009-2015 with the prospect to 2020 and the National priorities of oriented research, experimental development and innovations. There are various providers as the MŠMT (general responsibility for R&D policy, funding of R&D organizations including Universities, higher education institutions and large research infrastructures, support of international cooperation in R&D), GA ČR (support of basic research), TA ČR (support of applied R&D), MV (support of security R&D), MO (Support of defence applied R&D). These providers provide the support via their specific programmes in which space activities or related areas can be explicitly mentioned as preferred areas typically together with many other areas. The programmes are mainly bottom-up oriented. The real support of space projects is rather random than systematic.

4.4.2 INTERNATIONAL LEVEL

4.4.2.1 ESA Activities and Programmes

ESA activities and programmes together with the C3PFP represent the main tool to implement the NSP. Since the geo-return principle is generally applied in ESA, the Czech Republic considers all ESA activities and programmes as tools for incubation of Czech space capabilities.

4.4.2.1.1 Mandatory Activities and CSG

A) Science Programme

ESA Science Programme which is mainly focused on space science missions is financed from mandatory contributions of ESA Member States. Usually, ESA's Science Programme funds only the platform (satellite), its launch, and operations.

The scientific instruments on-board each of the Space Science satellites are funded nationally by the Member states involved except in the case of single instrument satellites as is the case of XMM-Newton, Herschel, Planck or Gaia. This approach to funding of the payload may change in the future. ESA currently proposes a pilot run with significant involvement of ESA in payload developments.

Czech industry made several successful bids on Science Programme tenders but the fair industrial return from the science programme was not met yet, which is unsatisfactory, despite such a problem have most of small to medium sized ESA Member States).

Since the Czech Republic cannot opt out the programme, effort must be made to build Czech industrial capacities in order to allow the industry to bid for contracts to build the satellite platform components and equipment.

Participating in Science Programme missions, industrial teams – in order to acquire high added value tasks that has the promise of building new industrial capabilities – need to be prepared well in advance in various optional programmes of ESA and also complementary national schemes. Complementarily, industry needs to be well positioned on international scene to be able to secure attractive subcontracts at subsystem or equipment level, such as Euclid structural subsystem in 2018.

Science Core Technology Programme (CTP) is a technology development programme that follows-up the Technology development element of DPTD (see below) and focuses on developing and demonstrating the maturity of critical technologies necessary for candidate scientific missions. The demonstration of the feasibility of these critical technologies is an essential prerequisite to enable implementation of the planned missions at an acceptable level of risk in terms of cost and schedule.

Even if the Science programme represents a part of the European institutional market and Member States have limited influence on contracts placed within the programme, the Czech Republic tries to push ahead activities with high added value to bring new expertise to Czech industry.

B) <u>Basic Activities</u>

The so-called "Basic Activities" are financed from mandatory contributions of ESA Member States. Basic activities include among others science, research, and development preparing of future activities of ESA. Basic Activities are at the core of ESA's activities organized in three blocks for:

- Preparing the future through Studies, Research, Innovation, and Dissemination (Block 1) that encompasses the Discovery, Preparation and Technology Development Programme (DPTD), Harmonisation and Education
- Guaranteeing Sustainability and Long-Term Capability (Block 2) that encompasses Long-Term Data Preservation (LTDP+), Earthnet and Core Technical Expertise (CTE), and
- Providing the necessary Infrastructure, Industrial Support, and Services (Block 3) that encompasses the SME Initiative, Engineering Laboratories and Test Facilities, Mission Operations Infrastructure, Sites and Common IT Investment and Standardisation

After CM16 the structure of the Basic Activities was modified discontinuing and/or transforming some of its elements (TRP, ITI, GSP, ECI) to a new set-up. As a result, within the Basic Activities ESA manages the following technology programmes and initiatives to guarantee that the necessary technologies are mature enough in due time:

- Discovery, Preparation and Technology Development Programme (DPTD)

  The purpose of the DPTD is to align the scope of basic activities to strategic directions, provide a balance within the Basic Activities between an ESA-wide development pull (coordinated early mission and technology development) and discovery push (new, potentially disruptive development, low-TRL). The programme is composed of three rather distinct elements (Discovery, Preparation and Technology Development) plus it encompasses technology harmonisation activities of ESA.
- Discovery element of DPTD

  This element covers discovery push activities. It relies on the insight of researchers and ESA experts, the academic community, industry, research institutions, and include (1) discovery projects, based on different sources including calls for ideas (internal and external), for paradigm shifts and game changers and (2) early 'blue sky' research on topics that are recognised as being potential breakthrough ideas but where it is not envisaged that these will be implementable within the next 10 years. Such research is typically conducted in the frame of post-doc level research (as for example by the Advanced Concepts Team), and in close collaboration with universities and research institutions. This strengthens the ties between ESA and Academia, and ensures that ESA has a constant influx of radically new ideas, benefits from recent research developments, contributing to spinning-in and spinning-out of ideas and concepts. The Discovery element encompasses former interdisciplinary studies and NPI, ITI and Startiger initiatives.
- Preparation element of DPTD

  This element includes phase 0/A studies for missions and activities to be later performed in the Science Programme and optional programmes and based on the programmatic demands identified by the ESA directorates. They are often performed via parallel contracts to allow for the best concepts to emerge and prepare industry in several member states. The outcome of these studies includes, but is not limited to early coherent baselines for future missions, exploitation scenarios, socio-economic benefits, required capabilities and technologies (including TRL and SRL assessments, estimates of cost at completion and schedules, analyses and proposals of way forward including a work plan and procurement policy.

- Technology development element of DPTD

  Technology development element serves as the core for the development of promising technologies in their early stages of production up to the laboratory experiments or proof-of-concept stage. Amongst its goals is to assess innovative/prospective technologies incorporating high development risks but also a high potential pay-off and to demonstrate their usefulness for space applications, providing ESA with a long-term technological capability to define new space missions and applications. Technology development element activities prepare, develop and mature technologies for future ESA missions. These activities are linked to the phase 0/A mission studies performed in the Preparation element of the DPTD or enable not yet defined future ESA missions as generic technologies which benefit all missions. These activities are often performed via parallel contracts to guarantee open competition for the best technological solutions, require direct links to ESA directorates and are fundamental in reducing future mission development times and risks. Technology development activities are conducted up to TRL 3-4. This enables a sufficient level of maturity of technologies and lower risk before they are transferred into dedicated maturation phases and missions in the optional programmes. Technology development in this element is pursued based on an interaction between the needs identified by ESA directorates for upcoming/planned missions and the technical capabilities identified by the technical and operations directorates of ESA. An ESA common technology development work plan is based on the outcome of the TECNET process and elaborates consolidated baseline development roadmaps for planned projects complemented by roadmaps for more disruptive/advanced technologies with a indicated potential injection upon successful reaching of adequate technology gates. The Technology development element encompasses former TRP programme and ECI initiative.

C) Others

ESA ensures access to mission data via LTDP and Earthnet programmes:

Long-Term Data Preservation Programme (LTDP)

The general preservation of science- and environmental data collected from space systems has been recognized as major challenge of today and it is consider as crucial condition for managing the future. Preservation element was inserted as a dedicated line on the ESA's general budget to support LTDP activities. This element addresses the preservation and integrity of science data generated by payloads and instruments on-board space platforms from ESA and ESA-managed Third Party Missions collected by D/EOP, D/SCI and D/HRE Directorates. It moreover aims at facilitating and promoting the access and exploitation of these data following a coordinated approach with the Member States data holders.

Earthnet

Earthnet ensures the access to non-ESA missions – Third Party Missions (TPM). TPM´s data covers data, which are collected by non-ESA missions and which bring the benefits mainly to the scientific community. At the same time the Earthnet plays the role of the framework for international cooperation in Earth observation (e.g. Tiger or Dragon cooperation programmes).

The Earthnet priority is to ensure the access to TMP´s data with best cost/user ratio, continue long operational TPMs (if requested by users) and provide historic data, but seeking to reduce duplicate archives (e.g. US missions) for which cost reduction can be achieved, and seek to transfer others to LTDP.

The TPM´s are periodically assessed from user benefits and excellence, accessibility, cost/investment, data policy, strategic and programmatic point of view and on that basis is judged their inclusion to the programme.

Earthnet brings the huge benefit mainly to the scientific users, which could obtain the easy and free-of-charge access to the TPM´s EO data for scientific use. It is the unique source of primary data usable in very wide range of scientific sectors and that makes the Earthnet interesting for the Czech scientific entities. Since 2018 Earthnet data are available also for start-up incubated on ESA BIC incubation programme.

D) CSG

Since 1975, ESA has contributed to the funding of the CSG and associated services, it being a main element of a guaranteed access to space for Europe. The CSG Launch Range is the system of facilities, and services, not part of any particular launch system[6] (Ariane, Vega or Soyuz), necessary to carry out a launch campaign, including safety and security so as to protect persons, property, and the environment against damage of all kinds. The CSG Launch Range includes facilities and services outside the geographical perimeter CSG. The ESA Member States contribute to the costs of maintaining the CSG Launch Range in operational condition (Reference MCO Costs) which are established on the basis of the Nominal Mission Model and covering all activities, services, and investments necessary to maintain the CSG Launch Range facilities safe and in working order in accordance with established practice with a view to maintaining them in, or restoring them to, a state in which they can perform the required function in accordance with applicable laws and regulations. They also include the necessary level of expertise to operate the CSG Launch Range facilities for the purpose of the ESA programmes and activities, and of the exploitation of Ariane, Vega, and Soyuz.

4.4.2.1.2 Optional Programmes

The following programmes are categorized according to the responsibility of each of the ESA programme boards.

ESA optional programmes can be divided into two main groups, i.e. envelope programmes and missions. In general, envelope programmes prepare technologies for missions to be used in commercial market. Many technologies are multidisciplinary in nature and can be developed and then used in different space domains. It can well happen that technology, which was originally developed in telecommunication domain is qualified in space exploration domain and gains flight heritage in Earth observation domain. The ESA optional programmes should be understood and used as complementary tools to each other. The envelope programmes also help to overcome the “valley of death”.

Envelope programmes are the main tools to incubate capacities and capabilities of Czech industry and academia. Missions are closer to or a part of so called institutional market and they have irreplaceable task to mature technologies, demonstrate them, qualify them and help them to get necessary flight heritage. Missions are also focused on building prototypes of satellites or other spacecraft which can serve as baseline for recurrent production. This kind of missions is very interesting from the return-on-investment point of view. Missions can also have scientific objectives. Objectives of missions are closely linked with provision of data to be further examined and used for various purposes.

In ESA there are also few programmes to support downstream application development.

4.4.2.1.2.1 Earth Observation

The family of EO Programmes consists of the Envelope programme, where is started most of the ESA´s EO activities, from mission development and implementation programmes, like Meteosat Third Generation (MTG), MetOp-SG and GMES/Copernicus Space Component and Earth Watch programme, which is framework for elements with specific interests.

a) Technology Programmes:

Earth Observation Envelope Programme (EOEP)

The *Earth Observation Envelope Programme (EOEP)* is the backbone of all EO activities in ESA and one of the largest programmes in ESA in general, since 2017 in its 5th Period. The Future Earth Observation –1 programme, which on the basis of the renewed ESA Earth observation strategy, proposes to continue the EOEP beyond its 5th period, rename the whole programme as Future EO programme that will span over the time-frame 2020-2028 and will consist of 3 independent segments which shall each last nominally 3 years.

The EOEP is composed from the following components:

[6] Launch system is fully integrated launcher together with the facilities necessary to manufacture and deliver the launcher elements, and to carry out the final integration of the launcher elements and the launch operations.

The Earth Explorer Component (EE) includes the definition, development, launch and commissioning of scientific missions aimed at the exploration of the Earth – both large missions (Core Missions) and smaller and less expensive missions (Opportunity Missions). EE includes both the platform and payload of the missions, as well as the associated ground segment.

The Development and Exploitation Component (D&E) consists from 3 blocks which covers the preparation of new missions, preparatory activities on EO science, technology and mission concepts, definition of Earth Watch and new Copernicus missions, pre-development of critical instrument elements and instrument models to a sufficient TRL, development activities for multi-mission ground segment, development of specific L2 products, incl. re-processing campaigns and cal/val, operations and maintenance of EE missions, supports the EO campaigns, new products and algorithms developments, support and expand the research community to exploit observations from future European EO missions, supports the transfer of scientifically proven EO research results into an operational concept – bridge the gap between "expert accessible" and "user accessible" information and strengthening the competitive position of European value-adding sector by the development of EO services.

The EOEP is periodical programme. Current 5th period runs since 2017 to 2021.

Since the year 2020, on the bases of the ESA Ministerial Council 2019, will be established the Future EO programme, as a successor of EOEP.

<u>Earthwatch – InCubed</u>

InCubed, as an element of Earth Watch Programme, offers financial and practical support to strengthen new industry initiatives. Through InCubed, companies developing innovative systems, components and products in the Earth observation business sector, can approach ESA at any time for support to make their venture technically viable and commercially competitive. Proposals could be about satellites, constellations, instruments or new application platforms, for example. Through these public-private partnerships, ESA aims to foster innovation and enterprise by supporting industry-led initiatives, faster ways of working, and business-oriented risk taking.

InCubed can potentially co-fund up to 50 % of a proposed venture. It can also provide access to ESA expertise and technical support. Proposals must be of sufficient technical readiness and market viability that private sector funding can be secured and further public funding will not be needed beyond the timescale of the InCubed activity.

InCubed has been launch in September 2017.

b) Missions:

<u>MetOp Second Generation (MetOp-SG)</u>

The MetOp-SG programme (referred to as EUMETSAT Polar System – Second Generation, EPS-SG, by EUMETSAT) aims at the development of the technologies and systems which will allow EUMETSAT to ensure continuation of the European meteorological service. MetOp-SG will enable the continuation of current EUMETSAT´s polar observation system without a gap in data provision to improve the accuracy / resolution of the measurements, and also to add new measurements / missions. The space segment consists of two series of MetOp-SG satellites, designated as Satellite "A" and Satellite "B".

The roles and responsibilities of ESA and EUMETSAT regarding their cooperation on the development of the MetOp-SG satellites will reflect the roles and competences of ESA as a development organization and of EUMETSAT as an operational organization. ESA will develop (based on specifications and requirements of EUMETSAT) the prototypes of both series and procure the additional recurrent satellites on behalf of EUMETSAT. EUMETSAT will finance the recurrent satellites, will be responsible for development of the ground segment and will operate whole system during its exploitation phase.

The MetOp-SG-A satellites will host Sentinel 5 modules on-board as In Kind Contribution of EU. The Sentinel missions are developing in frame of ESA´s GMES/Copernicus Space Component programme (period 3).

The programme has been started in 2013 and will be finished in 2022, when first of the EPS-SG satellites will be launched in the orbit.

Meteosat Third Generation (MTG)

The objective of the MTG mission is to provide Europe and, by extension, the international community, with an operational satellite system able to support accurate prediction of meteorological phenomena and the monitoring of climate and air composition through operational applications for the period of time between 2025 and 2037, possibly much longer.

The programme is implemented in co-operation with EUMETSAT, based on EUMETSAT's specifications and requirements. In the programme the Imager and the Sounder satellite are being developed. EUMETSAT will provide a contribution to the programme and will fund the recurrent satellites, the ground segment, the launch and LEOP services and the satellite routine operations.

GMES Space Component (GSC) / Copernicus Space Component

The objective of the programme is the preparation of Sentinel satellites, which will be the backbone of Copernicus system Space Component. General target of the programme is to fulfil the space-based observation EU requirements in response to European policy priorities. National utilisation of Sentinel data by Participating States will be supported by the right of data access, with agreed priorities in terms of operations planning. For this purpose a high level operations plan will be prepared, in the context of the Sentinel data policy.

Sentinel missions which consolidates all such national requests (i.e. from public user organizations), in addition to those from Copernicus services. The GSC programme, within its available resources (through ground segment development), also aims at the operational provision of satellite data for other European and national services.

Each GSC mission identifies a specific Earth observation data stream required to satisfy user needs for the corresponding services and information.

GSC 1&2 covered development of Sentinels 1,2,3,4 and 5 Precursor, incl. its respective ground segment. GSC-3 will cover development of Sentinel 5 and Jason-CS (Sentinel 6) incl. its respective ground segment.

EarthWatch

Several missions is developed on dedicated elements of EarthWatch programme (e.g. Fuegosat in the past, of Altius in current days). There are also elements dedicated on monitoring of climate change or development of Copernicus (formerly GMES) Services.

c) Applications:

Development of application is supported via EOEP-5, Block 4, resp. Future EO, block 4 in the future and specific Earth Watch elements (e.g. InCubed of GMES Service element). These programmes are described above.

4.4.2.1.2.2 Telecommunications

The Telecommunication optional programme is called *Advanced Research in Telecommunications Systems* (ARTES) and is divided into elements that can be subscribed separately. At ESA Council at ministerial level in 2019, a new ARTES 4.0 programme will be set up, with a new structure and modified rules, which will become applicable from 2020 onwards. The goal of this reform is to simplify the management of a 25 years old programme, which has grown too big and complex. The ARTES programme currently contains about 30 individual elements, which have different purpose, content and observe different rules. The programme elements evolve in time and sometimes need to be established between the meetings of ESA Council at ministerial level, to flexibly respond to SatCom market demand and opportunities. Therefore, the new ARTES 4.0 introduces a funding concept of Generic (GPL) and Strategic Programme Lines (SPL). The SPL are horizontal topics covering strategically important areas for Europe. The SPL will not be part of any ARTES element and they will be subscribed separately. The idea behind SPL is to create new financial containers of projects of a very different nature (studies, technology and application developments, user engagement and demonstrations), based on the premise, that they contribute to the same European strategic goal, e.g. Satellite for 5G (S45G), Secured SatCom for Safety and Security (4S), Optical Communication etc. Therefore, the current ARTES elements or individual ARTES projects will be moved into the SPL. Apart from that, the GPL and SPL will contain also new projects ready for funding allocation. The remaining funding in the current ARTES elements should be automatically transferred into the new corresponding structural elements (GPL and SPL) of ARTES 4.0 at the occasion of Space19+.

a) Technology Programmes

ARTES Future Preparation (FP) – Generic Program Line

FP is a strategic element for the whole ARTES programme including the agency itself, as the agency uses the programme for a lot of the preparatory work, studies and for proposing future ARTES elements. FP is dedicated to market analysis, technology, and system feasibility studies, to overcome the regulatory barriers, support the creation of satellite communication (SatCom) standards and future frequency needs. It is a preparatory element of the whole ARTES programme family and it forms the basis for the definition of ESA SatCom strategy. The activities are fully funded by the agency.

ARTES Core Competitiveness – Advanced Technology element (AT) – Generic Program Line

The objective of AT is to ensure long-term technological readiness of industry to respond to commercial and institutional opportunities. The content focuses on high-risk technological innovation in equipment and systems for SatCom within space, ground and user segment. AT supports the early development up to the point, when the critical functions and performance of the product have been verified (TRL 3 – TRL 6). The work under AT is often continued under C&G to complete the formal qualification and industrialisation of the product and prepare it for commercial exploitation. The AT runs an annual workplan of activities created by ESA on the basis of inputs from industry responding to a call for Ideas. The activities are funded by ESA 100 %.

ARTES Core Competitiveness – Competitiveness & Growth element (C&G) – Generic Program Line

C&G is dedicated to the development, qualification, and demonstration of new SatCom products or improvement of existing ones, assuring also their qualification and flight heritage (TRL 6 – TRL 8). The product can be either a piece of equipment, such as a part of satellite platform or payload, it can also be a user terminal or a full telecom system integrating a network with its respective space segment. Development of SatCom applications and services can be also part of this element. It seeks to improve the near-term competitiveness of the SatCom industry and its suppliers. The activities are co-funded by industry by 25-50 %.

Optical Communication (ScyLight) – Strategic Program Line

ScyLight is dedicated to development of technologies of optical SatCom, which are going to disrupt the traditional SatCom market in coming years. ScyLight provides both the ESA initiated invitations to tender according to an annual rolling workplan and the always open call for proposals to support industry-initiated activities. The projects can span from studies and technology developments to proof of concept and demonstration missions, which would show the maturity of the innovation to potential end-users. The programme concentrates on system level activities, optical terminals, photonics and optical payloads and quantum cryptography technologies and initial services demonstrations.

HydRON – Optical Communication Strategic Program Line Project

The aim of HydRON project is to develop and demonstrate the key in-orbit elements of a High Throughput Optical Network by means of demonstrator missions carrying innovative optical technologies for SatCom, covering also the ground segment, and its integration in terrestrial networks. HydRON will be the world's first all optical transport network at terabit capacity in space, by extending terrestrial fibre-based networks seamlessly into space by 2025, a concept also called as "Fibre in the sky". The concept is a priori not orbit specific and it can include different LEO/MEO/GEO scenarios. The first HydRON demonstrator (HydRON DM1) will be based on GEO orbit, the HydRON DM2 will create additional LEO node.

b) Missions

Neosat (NGP)

The aim of NEOSAT was to support the technological development, qualification and in orbit demonstration of Next Generation Geostationary Platform (NGP) product lines, addressing the 3 to 6 tons launch mass GEO segment needs of the future satellite operators. Since 2018 the NEOSAT programme has been producing flexible platform product lines capable of accommodating a wide range of SatCom missions and payloads. The programme has been partially funded by the large system integrators, which have the responsibility for in orbit validation and introducing the NGP on the SatCom market.

Iris SatCom Global Solution – 4S Strategic Program Line Project

Iris aims to supply a validated satellite-based communication solution for the European Air Traffic Management System (EATMS). The aim is to modernise European ATM communication system with digital data SatCom links, which will enable communication of ATM operators with the pilot during the whole flight. This possibility together with continuous position tracking enables to save time, fuel, CO_2 emissions and money for every flight, reduce flight delays and cancellations. The content and schedule of the Iris programme is harmonised with Single European Sky Air Traffic Management Research (SESAR) programme, which was launched 2006 by the European Community and EUROCONTROL. In 2017 the programme entered Phase II.2, corresponding to development and validation of the end-to-end performance of the SatCom system. The following Phase III should support in-orbit verification and certification of the pre-operational system and technical support to deployment of the full system.

EDRS Global – 4S Strategic Program Line Project

The programme's goal is the implementation of the European Data Relay System (EDRS) upgraded to a global coverage. Communication satellites and hosted payloads in geostationary orbit relay the data with high speed to and from non-geostationary satellites, spacecraft and fixed Earth stations through optical communication terminals and Ka band links. The first practical application of EDRS Global is to create the possibility to transfer high volume of Earth observation data in near-real-time from European Copernicus programme satellites (Sentinels) to Earth from any place around the globe. The system consists of EDRS-A payloads placed on board EUTELSAT 9B EAST, covering the territory from American East Coast and Europe up to India and the EDRS-C satellite (Hylas-3), covering the similar territory as a redundancy satellite. In 2023 the system will be extended by EDRS-D payloads, which will cover the Asia-Pacific region, thus securing the full globe coverage by high speed optical data highway.

GOVSATCOM Precursor

Govsatcom Precursor is a programmatic response of ESA to the EU GOVSATCOM initiative, which aims at creating a European SatCom system for governmental and institutional users in the EU and its member states. The GOVSATCOM services shall provide secure and guaranteed access to SatCom services for a wide range of applications for authorised users. In the frame of GOVSATCOM Precursor, the satellite operators and service providers will present the first public–private partnership projects. These projects will develop secure mission control systems and operations centres and demonstrate the benefits of pooling and sharing of SatCom resources to the users. The programme is being implemented in synergy with the Govsatcom demonstrations undertaken by the European Defence Agency. The agency will also support activities related to pooling and sharing of resources, the communication HUB development and support of national secured SatCom activities.

SAGA – 4S Strategic Program Line Project

Security And cryptoGrAphic (SAGA) is a Quantum Key Distribution (QKD) precursor mission in GEO orbit. Besides the technology challenges related to SAGA, ESA intends to address the important topic of end-to-end network security and the inclusion of LEO QKD cyber-secure solutions. This aims at developing and validating innovative space and ground segment in preparation of a European institutional QKD service, which may provide a backbone to a number of EU Govsatcom applications such as the secure interconnection of EU Embassies and of critical European infrastructure. The EC (DG-CONNECT) and ESA jointly cooperate to include SAGA precursor mission and the possibility of contributing missions as a space component of the pan-European QCI.

Triton-X (ARTES SAT-AIS)

The Triton-X is an already running project led by Luxembourg in the frame of ARTES SAT-AIS, which was joined by the Czech Republic in May 2019. The goal of this project is to develop and prepare for serial production of a series of an affordable microsatellite platform product lines for applications like telecommunication, Earth observation, situational awareness and in-orbit demonstration. The platform will span between 75-100 kg with a capacity to carry a payload up to 30 kg. The whole concept of Triton-X differs from most of traditional ESA activities, since it follows the New Space approach with relaxed requirements on components selection, not following the traditional ECSS standards and with fast project development plan to reach the first customers.

QKD Sat (ARTES Partner – Sub-element QKD)

The second example of ARTES element, which is already running and which was joined by Czech Republic in May 2019, is QKD Sat. The goal of the programme is to implement a demonstrator of world's first global quantum key distribution satellite network, which will be addressing the weakness of traditional encryption, and threats from quantum computers of the future (breaking the traditional keys). The applications of such system are to be found in telecoms, banking or services for national governments.

c) Applications:

Integrated applications promotion (IAP, Business Applications Space Solutions - BASS)

The IAP programme systematically searches for new services and applications that could benefit from capabilities of already existing space systems. It operates by a bottom-up, demand-driven approach, it collects the user requirements and defines their problems. The programme then implements feasibility studies of the potential new services and demonstration activities, which engage the end-users in pre-operational services validation with a prospect of taking over the service when it is mature enough. The projects have to utilise one or more existing space-assets, such as SatCom, Earth observation, satellite navigation, human spaceflight technologies and others. The programme builds upon cross-fertilisation across application disciplines, e.g. Transport & Logistics, Aviation, Safety & Security, Infrastructure & Smart Cities, Media & Broadcasting, Food & Agriculture, Environmental Resource Management, Energy, Maritime & Offshore, Tourism, Finance, Investment & Insurance, Health, Education etc. The programme runs different workplans with topics defined by ESA, but it contain also permanently open call for proposals, where industry can propose their own idea. The projects receive funding between 50-100 %, depending on the type of the activity and proposing entity. The IAP programme will undergo an overall transformation during the next ESA Council at ministerial level in the context of creation of ARTES 4.0. Apart from the current core of feasibility studies, demonstration activities and Ambassador Platforms, the new programme will feature also private funding opportunities, marketing and outreach and current activities of ESA Technology Transfer office, including ESA business incubation Centres (BICs) and Space Solutions Centres (SSCs). To better reflect its new mission, the programme will change name from Integrated Applications Promotion (IAP) to Business Applications-Space Solutions (BASS).

4.4.2.1.2.3 Navigation

a) Technology Programmes

European GNSS Evolution Programme (EGEP)

The European GNSS Evolution Programme (EGEP) was extended beyond its original timeline to maintain the competences of industry and ESA in technologies necessary for the future evolution of the European GNSS systems, EGNOS and Galileo. The programme included R&D activities composed of system definition and support studies, technology R&D, test-beds, system pre-developments and scientific GNSS related activities. The new activities were transferred from EGEP to EU funded Satellite Navigation programme (HSNAV) under Horizon 2020. Since 2015 all GNSS R&D activities have been funded through Horizon 2020, while ESA remains the implementing agency.

Navigation Innovation and Support Programme (NAVISP)

The NAVISP programme was set up at the last ESA Council at ministerial level in 2016. The main objective of NAVISP is to help European industry to succeed in the highly competitive and rapidly evolving global satellite navigation and PNT (Position Navigation and Timing) market for, while supporting participating states in enhancing their national objectives and capabilities in the GNSS and PNT sector. The programme is coordinated with GSA and European Commission, to cross-check the content of the project proposals and avoid duplication with EU projects under Horizon 2020. NAVISP is an important programme for the overall European GNSS landscape, capable of leveraging both ESA expertise gained through Galileo, EGNOS and European industrial base. The programme is implemented by three different programme elements, which offer both competitive procurement for

R&D (element 1) and bottom up project proposals for close to market activities (element 2), giving also special attention to specific PNT needs of member states (element 3).

4.4.2.1.2.4 Multiple-Domain Space Technology

General Support Technology Programme (GSTP)

The programme serves wide range of functions which all relate to increase of technology maturity in all ESA themes (except satellite telecommunication), development of space products, conduct in-orbit demonstration activities, promote a spin-in of multiple use technologies for utilization in space and enhance European technology non-dependence and the availability of European resources for critical technologies.

Main focus of the programme is to ensure the necessary continuity in the development of identified technologies, after their feasibility has been demonstrated in the basic TDE element of the DPTD programme, by supporting pre-developments and demonstrating flight suitability, before these technologies can be included at acceptable levels of risk in the future programmes of ESA. As such it is the essential tool to turn a promising technology into space-qualified product, bridging the so called "valley of death".

The GSTP is organized in three elements and one component.

GSTP Element 1 "Develop" covers technology developments for future missions, ground applications and tools. The activities performed under Element 1 are dedicated to the development of technologies, building blocks, components and test beds for projects and the economic operators, i.e. Small and Medium-Sized Enterprises (SMEs), large enterprises, industry, satellite operators, satellite providers, universities and research organizations from low TRL to qualification. Technologies to be developed within the element are selected from work plans published by ESA based on ESA needs.

GSTP Element 2 "Make" covers development of technology and products for commercial sustainability. Technologies to be developed within the element are proposed by industry, procured in direct negotiation and co-funded.

GSTP Element 3 "Fly" covers in-orbit demonstrations (IOD) of new technologies, preparation of future missions and small missions. The activities performed under the element aim at implementing IOD of technologies either as products in need of acquiring flight heritage, hosted payload or complete space missions (small spacecraft, cubesats etc.), conducting investigations and studies to prepare for future missions in particular breakthrough and new generation types of missions – conducting ad hoc small missions.

Precise Formation Flying Demonstration Component aims at implementing the phases C/D/E of the PROBA-3 mission in view of the demonstration of Precise Formation Flying (PFF) technologies and techniques.

Programme implementation rules allows Member States to precisely control which technologies are being supported as well as it provides guarantees the industrial return of the subscription.

4.4.2.1.2.5 Launchers

a) Technology programmes

Future Launchers Preparatory Programme (FLPP)

The general objective of the programme is to prepare competitive technologies for future launchers with low development and production costs, shorter launcher development duration (to less than five years) and lower development risks as well as to promote industry and new Member States participation in launcher development. This includes system studies, contribution to other ESA launcher development and exploitation programmes, implementation of future launcher developments, and contribution to progressive restructuring of the industrial organization for the next generation launchers.

The technologies developed in FLPP may find their application in one or more of the future launchers, be it the evolution of Ariane and Vega or their radical upgrades and completely new systems.

The programme strategy is to proactively invest into a diversified preparation portfolio of launch system development, key technologies, new manufacturing processes and integrated demonstrator before transfer into development programmes.

The developed technologies, if found mature enough and desired by specific launcher needs, are turned into particular products using other more launcher specific development programmes.

FLPP also funds studies of new launcher concepts – in the past it included studies of the next generation launcher (that later evolved into less revolutionary Ariane 6) while the programme will include micro launchers in the future.

b) Missions

Ariane and Vega Development programme (AVD)

For the purpose of the NSP the AVD is covered as "mission" because the objective is development of new flight hardware and flight itself – as opposed to maturation of technology for future use.

To cope with changing landscape in space transportation ESA Member States decided in 2014 to consolidate the European launcher offer as well as governance. As a result, new launchers were proposed and since then being eagerly developed: Ariane 6 and Vega-C.

Ariane 6 in particular was designed to maintain Europe's leadership in the fast-changing commercial launch service market while responding to the needs of European institutional missions and provide guaranteed access to space for Europe at a competitive price without requiring public sector support for exploitation. The exploitation cost of the Ariane 6 launch system is its key driver.

ESA is overseeing procurement and the architecture of the overall launch system, while industry is building the rocket with ArianeGroup as prime contractor and design authority. French space agency CNES is prime contractor for the launch pad. Ariane 6 provides a modular architecture using either two boosters (Ariane 62) or four boosters (Ariane 64), depending on the required performance. Two or four P120C solid-propellant boosters will be common with Vega-C, an evolution of the current Vega launcher. The synergies between Ariane 6 and Vega-C and large quantities for boosters to be manufactured is key to cost reduction for both launchers.

Vega-C is the evolution of Vega small launcher into more powerful and versatile one. It profits from the shared development with Ariane 6 of the first-stage motor, responds better to long-term institutional needs, increases launch performance by at least 300 kg and increases the flexibility for multiple payloads missions, notably with Small Spacecraft Mission Service (SSMS).

Light satellite, Low-cost Launch opportunity (LLL or L3) is an element of the AVD programme aiming at launch service for light payload using unified and standardized interfaces common for both Ariane 6 and Vega C. For Vega such interface effectively materialized as SSMS dispenser currently being readied for proof-of-concept (PoC) flight while for Ariane 6 an MLS adapter is planned as an adaptation of older designs. The challenge is indeed to reach common specifications for payload to make it indifferent for the customers with what launcher the flight is eventually performed. As a benefit, the launch service is supposed to be low-cost and timely.

Vega-E is yet another element of the AVD programme aiming at further improvements of Vega competitiveness by developing new cryogenic upper stage and electric propulsion module as well as improvements of key elements such as employing additive manufacturing or use of new attitude control system.

4.4.2.1.2.6 Human Space Flights, Microgravity and Exploration

European Exploration Envelope Programme (E3P)

E3P goal is to secure Europe's central role in global space exploration, deliver new results in both basic and applied science and offer a compelling vision of global endeavour enriching society and inspiring the next generation.

ESA has formulated the Europe's Space Exploration Strategy which has been formally adopted at CM14. This strategy is focused on the consolidation of exploration activities in a single E3P integrating the three ESA exploration destinations (LEO, Moon and Mars) as part of a single exploration process.

The first Period of the E3P includes extending the operation of the International Space Station (ISS) until 2024, contributions to the Russian-led Luna-Resource Lander, Science in Space Environment (SciSpacE) research, the first phase of Exploration Preparation, Research and Technology (ExPeRT) and ExoMars 2016 and 2020 missions.

The programme philosophy is evolutionary. It ensures continuity of existing activities while introducing new and complementary elements. This was particularly important in 2016 as E3P was conceived with its first Period of 3 years (2017-2019) of transitionary nature to facilitate the merging of then existing programmes (ISS Exploitation, ELIPS, ETHEPAP, Aurora MREP and ExoMars) into a single envelope.

The second Period 2020-2022 (E3P2) is the logical extension of the E3P Period 1 programme, to be implemented through a full envelope programme and based on four cornerstone mission campaigns Humans in Low Earth Orbit (ISS, astronauts, commercial utilization of LEO), Humans beyond LEO (LOP-G, ESM), Lunar robotic (cooperation with Roscosmos) and Mars robotic (ExoMars, MSR, Phobos backup). Further, there are technology development and system studies element ExPeRT and science instrument and experiment development element SciSpacE.

The programme has mission-oriented components as well as technology elements – but in terms of development and demonstration.

4.4.2.1.2.7 Space Safety and Security

<u>Space Safety</u>

The objective of the SSA programme, the ESA programme that actually covers the area of Space Safety, is to support the European independent utilisation of and access to space for research or services, through providing timely and quality data, information, services and knowledge regarding the environment, the threats and the sustainable exploitation of the outer space.

The SSA programme consists of Near-Earth objects (NEO), Space Surveillance and Tracking (SST) and Space Weather (SWE) elements. SWE element also covers studies and predevelopment of technologies related to the preparation of SWE L5 mission (dedicated SWE mission to Lagrange point 5).

The programme has been started in 2009 and will be finished in 2020. It is expected that the SSA programme will be substituted by the ESA Space Safety Programme (SSP) by 2020 (pending Space19+ decision). The SSP programme will ensure the continuity of existing SSA activities (Core Activity) and will introduce new Space Safety aspects (four Cornerstones Missions), organized as follows:

- **Core Activity**: continuity of existing SSA activities in following segments: a) SWE; b) Planetary Defence (former NEO segment); c) Debris and Clean Space (former SST segment).
- **Cornerstones 1, L5 mission**: an operational space weather mission at Lagrange point L5 to enable future provision of space weather nowcasts and forecasts with increased accuracy and timeliness.
- **Cornerstones 2, HERA mission**: a planetary defence mission to rendezvous with asteroid Didymos and perform a post-impact asteroid characterisation in order to validate the asteroid kinetic impact deflection technique. This mission complements early asteroid detection and warning activities with the development of deflection capabilities.
- **Cornerstones 3, In-Orbit Servicing/Active Debris Removal**: remediation dimension necessary for addressing debris – with a debris removal mission and at the same time support to the market of in-orbit servicing – one of the most important arising markets of the future.
- **Cornerstones 4, Automated Collision Avoidance System**: to ensure an adequate pre-emptive approach with respect to future activities and to enable the safe operation of mega-constellations in the field of applications – a Satellite Collision Avoidance Automation System.

<u>Space Security</u>

The Space Security is represented by a series of activities which are complementary to other programmes and domains. Their main goal is to protect space and ground infrastructures and provide space-based services mainly from man-made threats related to the Cybersecurity (jamming, spoofing and blinding of satellites, hacking of Ground stations etc.) that would negatively affect wide range of areas such as telecommunications, disaster management, transport applications, energy, food, water and resource management, surveillance, security of critical infrastructures, etc.

With respect to SatCom, ESA proposes to consolidate and increase its efforts under a new ARTES 4.0 thematic framework the topic of Secure SatCom for Safety and Security (4S). The aim is to increase European autonomy by 2025, the development of European B2B and B2C SatCom solutions, to foster resilience of European commercial digital market and to be competitive in global secure SatCom world, considering the significant institutional support in the USA and China. 4S will cover the full life-cycle across the complete range of the ARTES 4.0, from upstream preparatory activities and product development under Core Competitiveness to downstream activities, Partnership projects and Business Applications.

4.4.2.1.2.8 Scientific Payload

<u>Programme for the Development of Scientific Experiments (PRODEX)</u>

The PRODEX is a programme that provides resources for the development of scientific instruments or experiments, proposed by institutes, universities and industry in the Czech Republic. Usually these are selected by ESA for one of its own programmes in the various fields of space research (astronomy, astrophysics, planetary science, microgravity, Earth observation, etc.), however the PRODEX programme can also be used for funding of such activities for non-ESA missions.

These scientific instruments or experiments may be hardware or software projects, the development of which is usually carried out in collaboration with industry and in international partnerships. This has the potential to help strengthening relations between academia and industry.

4.4.2.2 EU programmes

4.4.2.2.1 EU Space Programme

The Space programme of the EU ("the Programme") will be established on the basis of current single space programmes Galileo and EGNOS, Copernicus and prepared GOVSATCOM and SSA since 2021. The Programme will be established by the Regulation and should cover the most of the space activities in the EU. The European GNSS Agency (GSA) should be replaced by the European Union Agency for the Space Programme, which will take over the activities of GSA and beyond that it will ensure another activities defined by the Regulation (e.g. market development, user uptake, security accreditation, exploitation, operation and others). The regulation will also establish the governance structure of the Programme, which defines the roles of the European Commission as the leader of the Programme, of the European Union Agency for the Space Programme (EUSPA) and also of ESA, which shall deliver technologies and satellites for the Programme.

The Programme shall include additional measures for ensuring efficient and autonomous access to space for the Programme and for fostering an innovative and competitive European space sector, upstream and downstream, strengthening the EU's space ecosystem and reinforcing the EU as a global player.

The Programme shall have the following main objectives:

- Provide high-quality and up-to-date space data, information and services, support EU political priorities;
- Maximise the socio-economic benefits from the in particular by fostering the development of an innovative and competitive European upstream and downstream sectors;
- Enhanced safety and security of the EU and its Member states;
- Provide long-term, state-of-art navigation and timing services via Galileo and EGNOS;
- Deliver accurate and reliable EO data, information and services via Copernicus;
- Enhance SST capabilities to monitor, track and identify space objects and space debris, provide space weather services and monitor NEOs;
- Ensure the long-term availability of reliable, secure and cost-effective SatCom services for GOVSATCOM users;
- Support an autonomous, secure and cost-efficient capability to access space;
- Foster the development of a strong EU space economy including by supporting the space ecosystem and by reinforcing competitiveness, innovation, entrepreneurship, skills and capacity building in all Member States and EU regions.

The Programme consists of the following components:

Copernicus

Copernicus is the component of the EU Space Programme focused on Earth observation. The objectives of Copernicus is to provide accurate and reliable information in the field of the environment and security, tailored to the needs of users and supporting other EU's policies, in particular relating to the internal market, transport, environment, energy, civil protection, cooperation with third countries and humanitarian aid.

Copernicus is considered as a European contribution to building the Global Earth Observation System of Systems (GEOSS) developed within the framework of the Group on Earth Observations (GEO).

The programme has been based on the Baven initiative from 1998 and developed in common effort of EU and ESA, where the European Commission formulates the whole project scope, services and data requirements and ESA is in charge of the space component including satellite development, associated ground segment and data provision from third party suppliers. In frame of the Space programme EU will ensure coordination of the space component, its evolution, design, development, and construction of the Copernicus space infrastructure, including the operations of that infrastructure and related procurement, except when this is done by other entities, and, where appropriate, access to third party data.

The structure of Copernicus has been formally changed to better fit the current status of the programme / component. The elements are namely the following:

- Data acquisition (Sentinels, contributing missions, in-situ data)
- Data and information processing through Copernicus Services (generation of added value information)
- Data access and distribution (infrastructure and services to ensure discovery, viewing and access to, distribution and exploitation of the data and information).
- User uptake, market development and capacity building.

Dedicated missions data and information produced by Copernicus (former) Core Services shall be available on full, open and free-of-charge basis, subject to some, mostly security limitations.

In the period of 2021-2027 there should be €5.8 billion allocated for Copernicus. In frame of the parthership with ESA on development of Copernicus, ESA should establish the Copernicus Space Component – 4 (CSC-4), optional programme. The CSC-4 should cover development and costs of the new High Priority Candidates Missions prototypes (new 6 Sentinels) and Sentinels New Generation. The EU budget should cover recurent satellites, operation, services and all other activities in Copernicus.

Galileo and EGNOS

The European satellite navigation programmes (EGNSS) are established by the GNSS Regulation (EU) No. 1285/2013 and cover all the activities needed to define, develop, validate, construct, operate, renew and improve the European satellite navigation systems, namely the Galileo and EGNOS systems, and to ensure their security and interoperability. The Galileo and EGNOS programmes aim to maximise their socio-economic benefits, in particular by promoting their use and fostering the development of EGNSS based applications and services. The EU budgetary appropriations assigned to the Galileo and EGNOS programmes for the period 2014-2020 is set at €7,071.73 million (2013 e.c.) and covers activities for completion of the deployment phase of the Galileo programme, the exploitation phase of the Galileo and EGNOS programmes and their management and monitoring. The operations of both Galileo and EGNOS are a responsibility of the GSA Agency in Prague. The Galileo system should reach the state of Full Operational capability with 26 satellites broadcasting the Open Service signal including Authentication by the end of 2021 (current expectacion – 2019) and on 2024 in case of PRS . In the following years, gradual introduction of other service including the Search and Rescue (SAR) return link, Public Regulated Service, High Accuracy Service and Commercial Authentication features. After 2020 the system should grow on average by two satellites launched per year till 2025. In the same five year period, the EGNOS system will be gradually upgraded from version 2 to version EGNOS V3 in 2025. The EGNSS activities beyond 2020 will be covered from the next EU Multiannual Financial Framework, for the period 2021-2027. The EU MFF budget for EGNSS activities under the new Space Regulation, currently under preparation, is proposed at the level of €9.5 billion.

Govsatcom

The EU Governmental Satellite Communications (Govsatcom) is a new component of the EU Space programme after Galileo and Copernicus, mentioned also in the Space Strategy for Europe and the European Defence Action Plan. The general objective of Govsatcom is to ensure affordable, reliable, guaranteed, secured and cost-effective SatCom services for EU and national public authorities managing security critical missions and infrastructures. Govsatcom initiative is situated at the interface of security, space, and defence policies and its' preparatory steps have been taking place since 2013. Govsatcom will ensures the EU's strategic non-dependence and it will primarily serve EU and national civil protection agencies, police and military forces and governmental entities which require secure SatCom for crisis management, surveillance and diplomatic networks. The Govsatcom infrastructure will be composed from both private SatCom systems and national civil and military SatCom systems, therefore the defence forces will be also part of the users (dual-use). The idea is to pool the existing secured SatCom capacities from member states and share them with authorised users, according to priority and demand. After 2025, an evaluation of potential upgrade and enlargement of the system by a new dedicated EU Govsatcom satellite infrastructure should be done, taking into account the actual demand for Govsatcom services. The legislative proposal for Govsatcom was prepared by European Commission in close collaboration with ESA, EDA and EEAS and was negotiated with member states, as an integral part of the Space regulation package, currently under negotiations. The EU budget for Govsatcom is proposed to be less than €500 million, sharing this envelope with SSA.

SSA

The European commission turn its attention to Space Safety in 2015 by introduction of the EU Space Surveillance and Tracking Support Framework (SST SF). The SST SF, implemented by SST Consortium, is designed to enhance Europe's services, capabilities and autonomy in the area of Space Debris. Nowadays, the SST SF is providing specific services on a regular basis (namely Conjunction Analysis, Re-Entry Analysis and In-orbit Fragmentation analysis), but does not meet the autonomy requirements. In this regard, sharing of relevant Space Debris information with other international stakeholders is crucial until significant new investments are made in the SST area.

By adopting the EU Space Programme regulation, the European Commission confirm its will to cover also other missing elements of SSA, namely the Space Weather (SWE) and Near Earth Object (NEO). At the beginning of 2019, there is no clear view yet on the content and range of forthcoming EU SSA activities – in every way, the whole intended transition of EU SST SF into EU SSA represent an opportunity for Czech Industry and Academia with relevant expertise in various aspects of SSA problematics.

The EU budget for SSA is proposed to be less than €500 million, sharing this envelope with Govsatcom.

4.4.2.2.2 Horizon Europe and related EU tools

Horizon Europe, successor of Horizon 2020, is the Framework Programme for Research and Innovation 2021-2027. The goal of the Horizon Europe is to support the creation and diffusion of high-quality knowledge and technologies, to strengthen the impact of research and innovation in developing, supporting and implementing EU policies, to support the uptake of innovative solutions in industry and society to address global challenges and promote industrial competitiveness; to foster all forms of innovation, including breakthrough innovation, and strengthen market deployment of innovative solutions; and optimise the delivery of such investment for increased impact within a strengthened European Research Area.

Space activities will be a part of the cluster "Digital and Industry and Space". It is expected, that Horizon Europe will support this kind of activities of the Space programme EU:

- Application and service development on Earth observation, satellite navigation, satellite telecommunications, support in user uptake;
- Satellite navigation receivers;

- Scientific data processing;
- Technology development (mostly in cooperation with ESA), potentially supports some kind of activities in launcher domain;
- Innovations on space and space related domains (cross-fertilisation with Artificial intelligence, Big data processing and ICT in general).

There is also expected some Joint Technological Initiative in frame of the programme.

Strategic planning and programme activities should be implemented as Annex I of the Specific Programme. The Strategic Planning process aims to implement Horizon Europe's programme-level objectives in an integrated manner and provide focus on impact for the Programme overall and coherence between its different pillars; promote synergies between Horizon Europe and other EU Programmes, thus becoming a point of reference for research and innovation in all related programmes across the EU budget and non-funding instruments. The Specific programme should support the following:

- Expansion of Copernicus Core services, research for space data assimilation and exploitation, robustness and evolution of services, sustainability of supply chains, sensors, systems and mission concepts (e.g. High Altitude Platforms, drones, light satellites); calibration and validation; sustained exploitation of services and impact on societal challenges; Earth observation data processing techniques, including big data, computing resources and algorithmic tools. Next generation systems development for challenges, such as climate change, polar and security; extension of the Copernicus product and service portfolio;
- Developments to support robust EU capacity to monitor and forecast the state of the space environment e.g. space weather, including radiation hazards, space debris and near Earth objects. Developments of sensors technologies and new service concepts, such as space traffic management, applications and services to secure critical infrastructure in space and on Earth;
- Secure Satellite Communications for EU governmental actors: solutions supporting the EU's autonomy for governmental users including associated user equipment and architectural, technological and system solutions for space and ground infrastructure;
- SatCom for citizens and businesses: integration of cost-effective, advanced SatCom in the terrestrial networks to connect assets and people in underserved areas, as part of 5G-enabled ubiquitous connectivity, IoT, and contributing to the Next Generation Internet (NGI) infrastructure. Enhancing the ground segment and user equipment, standardisation and interoperability, and preparation of quantum key communication by satellite to ensure EU industrial leadership;
- Non-dependence and sustainability of the supply chain: increased TRLs in satellites and launchers; associated space and ground segments, and production and testing facilities in complementarity with ESA. To secure EU technological leadership and autonomy, improved supply chain sustainability at cost-effective and affordable conditions, reduced dependence on non-EU critical space technologies and improved knowledge of how space technologies can offer solutions to other industrial sectors; and vice-versa;
- Access to space and space science.

In addition, there are expected some links to the sector of energy and mobility.

4.4.2.3 EUMETSAT programmes

The Czech Republic through its membership in EUMETSAT formally participates in all of the mandatory programs of this organization. Presently, from the operational perspective, the main and most important EUMETSAT programmes are the Meteosat Second Generation Programme (MSG) and EUMETSAT Polar System Programme (EPS). Prime utilization of data from these two mandatory programs at the national level is within the duties of the Czech Hydrometeorological Institute (CHMI). The Czech Republic does not participate in any of the optional programmes of EUMETSAT. Among the future mandatory programmes, preparation for the next generations of EUMETSAT satellites – Meteosat Third Generation (MTG) and EUMETSAT Polar System – Second Generation (EPS-SG) are being carried out by EUMETSAT and its Member States recently.

Meteosat Second Generation

The Meteosat Second Generation (MSG) is presently the most important EUMETSAT programme, providing operational weather and climate data not only to the EUMETSAT Member States, but contributes with these also to the global Earth weather and climate observations. The MSG programme consists of four geostationary satellites, MSG-1 to MSG-4. MSG-1 (renamed to Meteosat-8 once in orbit) was launched in 2002, MSG-2 (Meteosat-9) in 2005, MSG-3 (Meteosat-10) in 2012 and MSG-4 (Meteosat-11) in 2015. Expected, recently prolonged lifetime of the MSG system is approximately until 2030. From 2021/22 on, the MSG programme is planned to be gradually replaced and upgraded by Meteosat Third Generation (MTG) satellites.

The main advantage of geostationary satellites is their regular, frequent imaging of the entire globe or its parts – for MSG satellites the repeat cycle is 15 minutes for the global coverage, and 5 minutes for the regional Europe coverage; for MTG satellites it will be 10 and 2.5 minutes respectively.

EUMETSAT Polar System

The EUMETSAT Polar System (EPS) began with the launch of MetOp-1 satellite in 2006, followed by MetOp-2 launch in 2012, and has been completed with MetOp-3, launched in 2018. The MetOp satellites share a low-Earth orbit with similar NOAA-19 (the last satellite of the NOAA-POES series) and NOAA-20 (the first of the NOAA-JPSS new-generation series), U.S. polar-orbiting satellites, forming thus a "joint polar system". While the polar satellites do not provide as frequent Earth observations as the geostationary satellites, the polar orbiting weather satellites provide additional important daily observations, not presently available from the geostationary satellites (namely advanced atmospheric soundings, which are one of the key inputs for numerical weather prediction models).

5 ANALYSES AND MEASURES

Space activities are a unique tool to influence economic development by creating virtuous examples and best-practices to be used in other sectors of the economy. The economic impact considered as a "return-on-investment" in space activities is in the order of a factor of 4 – 5, some analyses show the factor even much higher.

To achieve the vision and the objectives of NSP it will be necessary to take a number of measures:

5.1 IMPROVING NATIONAL INSTITUTIONAL SETTINGS

Analysis:

The establishment of the Coordination Council for Space Activities was a significant improvement of the situation as it was before 2011 by ensuring transparency and participation to all institutional stake-holders. However, the Czech Republic should further optimize the way that the public sector approaches the area of space activities – in particular to eliminate current fragmentation of execution powers, increasing the effectiveness and efficiency of public administration and public expenditures, improving communication between public and private sector, and using synergies with other areas and concentrate the expertise. This is a point already recognised in 2010 NSP and 2014 NSP. As a following step forward, the establishment of a public national space agency should be considered.

During the last period, new challenges raised. Space technologies has important overlap to aviation and defence in dual use. To maximise synergies, close interaction among these three sectors needs to be established. The national space agency could be the appropriate body to handle these synergies. Also in the field of space downstream application, special approach is needed. All respective powers cannot be centralised as users will stay within the competent ministries or other governmental bodies. However, clear and efficient interface has to be established for unified implementation or coordination of system issues as market uptake, market development etc.

The national space agency could be also a single point of access implementing a comprehensive package of measures to support the entire space sector.

Measures:

(1) **To take steps to establish a national space agency**: The possibility to establish a national space agency should be further analysed and based on the analysis the next steps should be defined and possibly implemented.

5.2 STRENGTHENING THE POSITION OF THE CZECH REPUBLIC IN INTERNATIONAL RELATIONS

5.2.1 EXPLOITING MULTILATERAL INTERNATIONAL COOPERATION

Analysis:

The Czech Republic benefits from its membership in international organizations. However, it also should find new ways how to exploit the opportunities arising from such memberships. Close coordination within respective delegations of the Czech Republic and between such delegations and other relevant Czech bodies and their representatives to be able to maximally support priority areas. Close communication and good relationships with representatives of international organizations should be further built at various levels.

Synergies among various activities have to be actively identified to enable use and further development of industrial capacities and capabilities and maximize the return on public investment of the Czech Republic to space related activities. In this respect the Czech Republic should exploit all opportunities connected with its membership in international organizations and motivate Czech entities to use their capacities and capabilities and participate in activities of these international organizations.

There are also some international organizations or entities yet which may help the Czech Republic to open new perspectives and opportunities for international cooperation and increase benefits of space for state, its industry, academia and society. Among those which need special attention belongs Eurisy.

To be able to define which ambitious projects the Czech Republic might be part of, using its capacities and capabilities, its possible participation in international fora as the International Space Exploration Coordination Group (ISECG) should be also analysed.

Measures:

(2) To become a member of Eurisy: The Czech Republic, e.g. through the MD, should become a member of Eurisy to strengthen its position in international space community and to be able to share and discuss lessons learned on how to develop and use space downstream applications in various areas.

5.2.2 ESTABLISHING BILATERAL INTERNATIONAL COOPERATION

Analysis:

The Czech Republic maintains diplomatic relations with the majority states of the world. There are many general economic, industry and scientific and technical agreements which the Czech Republic or former Czechoslovakia concluded over the years. These agreements complemented by general legal frameworks of international organizations with broad membership basis enabled open cooperation In various sectors including space.

However, just few space-oriented bilateral frameworks have been initiated and formalised so far (France, Luxembourg, Brasilia). Despite of this fact, there are many examples of excellent bilateril cooperation, especially with European states, which goes without formalised legal or political act. Various bilateral meetings at academia, industry and state levels are regularly organized and they bring benefits to both sides.

On the other side, it is highly suitable to proceed to conclude a legal or political acts when specific issues beyond usual cooperation need to be address. Such an act may demonstrate joint will and interest to cooperate in specific area and may give to the counterpart certainty of sustainibility.

Measures:

(3) To deepen the existing and establish new partnerships: The Czech Republic should analyse if the present bilateral international cooperation should be further formalised by a legal or political act. There are also states with which the Czech Republic has not started any cooperation in space yet; possibilities for new partnerships should be further explored.

5.3 CZECH SPACE CAPACITY AND CAPABILITY BUILDING

In the Czech Republic there are several technologies that are sufficiently advanced to be applicable relatively easily to space programmes or applications. However, only the companies with the determination and motivation to overcome the initial hurdles will be able to move into the space arena. Among the challenges are the strict project management, standards and documentation requirements and the limited profit margins that ESA contracts allow.

The space business in the Czech Republic focuses especially on innovative SME. Specific measures to support SME and their innovative behaviour should be devised. These measures should also cover protection of IPR, including patent registration and related support.

To stimulate new applications development some suitable platforms or schemes should be further exploited. It is necessary to ease the transfer of ideas of new promising applications to the market. In this case the ESA BIC is one of suitable supportive tools.

The following actions should be implemented in order to stimulate the space sector in the Czech Republic:

- Intensive awareness raising;
- Continuation of a dialogue with promising industry, academia and end-user communities;
- Demonstration of successful applications;
- Stimulating demand (through a mix of workshops, success stories, etc.);
- Promotion of capacity building, business incubation and technology transfer;
- Stimulation of new application development through suitable platforms or scheme at national level;

- Stimulation of the sector by participation of the Czech Republic in respective ESA and EU programmes as it is the key to European and global markets;
- Organization of events for networking between industry and the academia, ideally in cooperation with academia from the old ESA Member State providing background and inspiration from their much longer experience in industry-academia interactions.

5.3.1 *AWARENESS RAISING*

In order to ensure a high level of awareness in general public and knowledge of the professional community concerning the importance of space activities, their benefits for individuals and entire society and respective opportunities, there is a need for close collaboration and involvement of various player both of public and private sector to awareness raising activities.

5.3.1.1 General Public

Analysis:

Although the broad scope of awareness raising activities for the general public has been carried out, the general public knowledge on space activities is still insufficient in the Czech Republic. The main obstacle to the dissemination of information on space-related activities and its benefits among the general public can be seen in random interest in space-related themes among the traditional media channels (TV, radio, press, journals).

Another point that has a negative impact on raising awareness in the field of space activities within the general public is the fact that the relevant information is available in the form poorly understandable to the laymen. The terms "space" and "space activities" themselves seem to be far off daily life for them which may discourage them to further discover the real content and realize that they are more dependent on space and space activities than they expect.

The majority of the undertaken awareness raising activities for general public is focused on adults. The negative impact on the awareness of children and youth in space activities can be seen again in the lack of interest across the traditional media channels and in the lack of tools which may raise the real interest.

More attention should also be paid to awareness raising about current issues concerning the space activities and their benefits for the national economy towards decision makers.

It should be noted that schools do not generally impose an emphasis on involving space topics into current educational curriculums and extracurricular activities.

Measures:

(4) To intensify awareness raising: It is necessary to promote new awareness raising events and support the existing ones, broaden the range of participants and extent the existing informative web portals and use of social networks. Information for the general public must be presented in a simple form, preferably on real examples of the use of space technology and applications in the daily lives of people and real and measurable socio-economic benefits that space activities and applications bring to the whole society. IPR awareness rising should be an integral part of these kind of events.

(5) To cooperate with media and cultural, educational and awareness rising facilities: It is necessary to be focused on the identification and subsequent establishment of cooperation with appropriate media (TV, radio, newspapers, journals, etc.) and to build and maintain an active network of contacts to ensure dissemination of space-related information to the general public. It is also necessary to strengthen cooperation with cultural, educational and awareness rising facilities systematically engaged in awareness raising in the area of the space activities like observatories and planetariums, science centres and parks for general public, etc.

5.3.1.2 Professional Public

Analysis:

The level of awareness and knowledge of professional public about space activities in the Czech Republic can be considered as satisfactory. A wide range of implemented activities with an appropriate support provided by the public sector is continuously promoting the awareness within the professional public. It is worthy to note that the activities of professionals are closely associated with their businesses, employments, scientific activities, efforts to find new markets or with a personal interest in the very issue. Therefore, they actively and regularly ask for relevant information.

Measures:

(6) To promote opportunities and possibilities for professionals: The range of the informative support provided to industry and academia on opportunities and possibilities for development of their capacities and capabilities in the field of space activities, with a particular focus on the activities of ESA and EU, including information about IPR and it´s importance, might be further developed through seminars, conferences, information and industrial days, web portals, newsletters and other media channels.

(7) To promote space activities of the Czech Republic abroad: It is necessary to seek for the opportunities in the field of strengthening the international cooperation. In this respect it seems to be necessary to further spread awareness about the national space policy of the Czech Republic on international level and display the capacities and capabilities to other states and relevant entities as large system integrators.

5.3.2 EDUCATION AND TRAINING

5.3.2.1 Primary, Secondary and High Schools

Analysis:

The level of teaching STEM subjects seems to be quite satisfactory, but there is still the lack of appropriate emphasis on teaching supplementation, which will raise the interest of the young generation to pursue careers in the relevant fields of space activities.

Similar situation can be recognized at the high schools moreover with the lack of appropriate optional educational training courses and supporting activities like a realization of hands-on student's projects.

Measures:

(8) To continue in training teachers on how to attract students to STEM subjects: Teaching of STEM subjects at primary, secondary and high schools must be adequately complemented by extracurricular activities with overlap in space activities (e.g. courses, workshops and leisure activities on astronomy, astronautics, physics, etc.) leading to a deeper understanding of the particularities of scientific and technical disciplines to inspire youth and keep their initial interest in science and modern technologies.

The objective is to teach STEM subjects in an entertaining and spontaneous way, in which students learn how to use science and technology in various fields of everyday human activities. The main responsibility on how the STEM subjects are taught lies with universities through teacher training in initial education. The Ministry of Education, Youth and Sports may address the development of this issue within the further education of teachers.

(9) To inform high school students and teachers about opportunities: At high schools, the emphasis should be placed on deepening the knowledge and understanding of specifics of space and scientific and technical disciplines related to space. There is a need rise the awareness about IPR with this regards. It is also essential that the foreign courses and hands-on projects opportunities in the field of astronautics are identified. In this case, it is necessary to continuously raise awareness about these activities among high school students and teachers, using international cooperation with foreign institutions (especially within ESA).

5.3.2.2 Universities and Ph.D. studies

Analysis:

The prime source of space related expert personnel is located in the Czech universities although the limited number of space related university programmes exist. Other teaching courses on space science and technology are also provided in some universities using existing small space projects as opportunity for hands-on activities (university robotics research, partial realization of the CubeSat nanosatellites, etc.).

The number of educational programmes taught at the Czech universities to provide experts in the field of hardware for space flight experiments is smaller when compared to software engineering – however, with a rising trend. Still, there is missing programme of Space System Engineering in the Czech Republic and current geographical study programmes should be more oriented to prepare new experts on EO data processing.

With regards on the activities, which will GSA (future EUSPA) ensure in the field of security of EU Space Programme in the future, there will be high demand on experts skilled in this domain.

With regard to foreign options, number of students able to study at foreign universities (i.e. International Space University, TU Delft, etc.) is limited by lack of financial resources, lack of awareness and perhaps also in a lax approach of students in utilisation of the possibilities in the field of education offered by the international institutions. This is a long-term issue that needs to be treated by unified and clearly coordinated approach of responsible authorities.

Measures:

(10) To strengthen the international cooperation to create new opportunities for Czech graduates and undergraduate students: Foreign institutions (having their own educational corporate programme – space agencies, major space industry players, etc.) and universities could enlarge list of opportunities for Czech graduates and undergraduate students (e.g. ESA´s Student Internships and Young Graduate Trainee Programmes and hands-on projects of ESA Education Office).

(11) To establish national contact point (NCP) for "University and Ph.D. space studies": NCP (e.g. extended ESERO) could e.g.:

- **(a)** Raise awareness;
- **(b)** Actively involve Czech universities, Czech industry and foreign companies/institutions;
- **(c)** Promote communication between Czech universities and relevant stakeholders (government bodies, industry, scientific institutions, etc.);
- **(d)** Implement separate educational projects;
- **(e)** Support students to get access to specialized educational institutions and industry inside or outside the Czech Republic giving them relevant specialist and business skills that are needed in both upstream and downstream;
- **(f)** Help to find funds for preparation of scholarship programmes for Czech students;
- **(g)** Encourage short and long-term internships and courses;
- **(h)** Support realization of hands-on student activities with high-added educational value (e.g. full realization of CubeSat projects).
- **(i)** Rise the awareness about IPR.

(12) To establish Space System Engineering study programme: Support the establishment and development of Space System Engineering study programmes using available financial and methodological tools. The objective of measure, which reflects the current needs of industry and will of the academia represented in the committees of the Coordinating Council for Space Activities, is the establishment and accreditation of at least one such programme in the Czech Republic. The programme should also demonstrate good cooperation between academia and industry, which is directly or indirectly involved in the implementation of the programme.

(12a) Make an effort on preparation and further accreditation of the study programme focused on space programmes security. The programme should be prepared in cooperation with relevant industrial and academic players in the field of security and with international organizations.

5.3.2.3 Young Professionals & Life-long Education and Training

Analysis:

The educational programmes for young professionals in ESA were attended by just a few Czech students. ESA's Young Graduate Trainee (YGT) programme has a limited capacity. The programs of the International Space University are quite cost-demanding.

The Czech Republic has not introduced a specialised training scheme so far, even if attempts have been made. The failure to implement a training scheme was always due to lack of suitable funding source.

These programmes can be also used to support the life-long educational space-oriented vocational training courses or schemes (how to write a proposal, IPR, ECSS Standards, etc.).

Measures:

(13) To inform Czech graduates and postdocs about opportunities: More attention should be paid to raise awareness among Czech graduates and postdocs about ESA's Young Graduate Trainee programme and Postdoctoral Research Fellowship programme and student programmes provided by the ISU. With regard to demanding tuition fees, the establishment of supporting tools like student loans or scholarships should be analysed and possibly implemented.

(14) To establish a Czech Trainee Programme: The Czech traineeship framework should be established, supplemented by the internship/trainee framework for the young professionals across the Czech and foreign industry together with Czech Trainee Programme within ESA, preferably using C3PFP (see Chapter 5.3.5.1) for funding until other sustainable funding source is identified. It is advised to maximise throughput of the training scheme in the first two years of its implementation to cope with the deficit accumulated over the past years. Later the throughput could be adjusted.

(15) To organize life-long educational space-oriented vocational training courses: Courses on various topics, e.g. how to write a proposal, IPR protection, ECSS Standards, etc., have to be further offered to increase relevant skills in industry and academia.

5.3.3 COMPETITIONS

Analysis:

Even if there are lot of opportunities to submit new ideas to various competitions calls, the interest to do so among target groups is unstable, despite that benefits for a company or individual when the proposals are accepted can visibly materialise in their future activities or carriers.

Measures:

(16) To improve promotion of competitions among target groups: Presentation of success stories and benefits can increase motivation of companies and individuals to participate in competitions. Broader network of partners involved in competitions can bring more opportunities to participants. Effective interface to other tools needs to be further explored and promoted.

5.3.4 INCUBATION AND TECHNOLOGY TRANSFER

Analysis:

ESA Business Incubation Centre (ESA BIC) and ESA Technology Transfer Broker (TTB) activities should be further supported to accelerate the technology transfer to and from the field of space activities and enable the establishment of new companies and the further development of the existing ones.

The recent transfer of implementation of ESA BICs and TTBs into ARTES BASS (Business Applications-Space Solutions) programme promises more efficient implementation of both due to inherent experience of the ESA's telecommunication directorate with business-heavy environment.

ESA BIC concept has already proved its value in the Czech Republic and there are more promising start-ups to be possibly incubated than the actual incubation capacities of ESA BIC Prague in the cities of Prague and Brno. There is a need for a discussion how to incubate more risky ideas to increase possible benefits for economy and at the same time to keep the success rate still relatively high.

TTB filled a gap, since it is constantly seeking for new use cases of application of space technologies in the frame of traditional industries a services, to upgrade their technologies and innovate processes, e.g. through the calls for Technology Transfer Demonstrator Competition.

The Czech Republic currently intends to utilise the Ambassador Platform, because it could facilitate the engagement of new industrial companies including SMEs into space applications by creating awareness, providing consultation services and mentoring. Potentially, it could do the same for the industries developing new technologies in ARTES Core Competitiveness Programme. The Czech Republic should also explore the concept of an ESA Space Solution Centres (ESA SSC), which integrates the ESA BIC, TTB and Ambassador Platform into one unit. ESA SSC is a new framework to boost the growth of space related businesses and ventures. By joining the networks of BICs, TTBs and

Ambassador Platforms a full range of innovation support tools will be offered to start-ups and SMEs in space and in non-space in a centralized manner in three basic steps: Identification & Ideation, Feasibility & Incubation and Promotion and Growth.

Measures:

(17) To extend incubation capacities of ESA BIC in the Czech Republic: ESA BIC should offer enough incubation capacities to help the maximum of start-ups with potential to put its products and/or services to the market and bring benefits to the Czech Republic. A possibility to open new branch of ESA BIC in another city in the Czech Republic has to be also considered.

(18) To continue and extend the activities of TTB: The TTB should continue its' search for new opportunities of transfer of space technologies into non-space and vice versa. The TTB is a great tool with a big potential of engaging both new and established companies into space business and create success stories to promote the benefits of space technologies for the public audience and media.

(19) To establish the Ambassador Platform in the Czech Republic: The platform is additional tool, which can enlarge both the Czech space industry and the user base of space technologies and services. The platform should help the newcomers with doing business with ESA, raise the awareness of project opportunities and funding mechanisms of ARTES programme, especially in downstream, but also in upstream topics.

(20) To explore the concept of an ESA SSC: The Czech Republic should also investigate the new concept of ESA SSC, evaluate its potential benefits and consider implementing one inside the country. The Czech Republic should seek feedback from ESA Member States, which are already running a similar organizational model at home, namely Portugal, Ireland and Belgium.

5.3.5 FUNDING AND EXPLOITING APPROPRIATE PROJECT SUPPORT TOOLS

Analysis:

There is a number of tools, which can be used to support the development of space capacities and capabilities. However, the only existing tools specifically oriented to space activities in which the Czech Republic participate today are the activities of international organization of which it is a Member State, such as ESA, EU and EUMETSAT. Other tools on both national and international level are of general or nature or relates to space just partially and therefore their use for support of the development of space capacities and capabilities is rather limited.

Project support tools should be designed, if possible, and/or at least used in order to maximise return-on investment and benefits for the Czech Republic, its industry, academia and citizens. This is the way how the C3PFP was prepared and approved by the Government of the Czech Republic.

However, the influence of the Czech Republic on design of international project support tools (meaning programme, project, initiative or activity) especially in ESA and EU is limited since compromise among states has to be achieved to create such project support tools. In such cases, the Czech Republic has to evaluate whether or not the final setting of the respective project support tool gives enough guarantees that its interests can be advanced. Based on this assessment, a decision whether it is useful to support and participate in such project support tool should be taken along with allocation of funding.

The main tools are C3PFP and ESA optional programmes. Without appropriate level of funding, the Czech Republic would not have a tool to support Czech space activities, including capacity and capability building of Czech industry and academia.

Level of funding of the project support tools should correspond with the ratio of benefits they can bring to Czech economy, reputation and society.

Measures:

(21) To secure appropriate funding of relevant project support tools: Funding of project support tools should correspond with the ratio of benefits they can bring to Czech economy, reputation and society. Details see in Chapters 5.3.5.1 and 5.3.5.2.

(22) To use project support tools in conformity with NSP: The use both national and international project support tools should meet specific objectives defined in Chapter 3.2.1.1 to maximal extend possible.

5.3.5.1 National level

Analysis:

National space programme should support a sustainable growth of the capacities and capabilities of the Czech industry and academia, their competitiveness and their preparedness to participate in European or international programmes. It should also enable the implementation of ambitious Czech space missions or participation of the Czech Republic in international missions. The national space programme would be a good tool to complement the development done within ESA programmatic frame.

No complex national project support tool for the space activities respecting their specificities exists nowadays in the Czech Republic. If such a tool is to be established, the systematic approach to support the space R&D is needed in the Czech Republic. There is also a need to more efficiently use the present frameworks of support of the international cooperation in R&D to motivate Czech entities to cooperate with their foreign counterparts and create stable consortia to be further active e.g. in programmes of EU or ESA.

The C3PFP in combination with PRODEX programme can fulfil to certain extend the role of the national space programme nowadays. ESA technical expertise and managerial competences represent great advantage in maximising benefits of respective public investments. Such expertise and competences do not exist at the national level today.

The C3PFP is the only tool of its kind in the Czech Republic. It has already proved its unique role in capacity and capability building of Czech industry and academia. Profile of C3PFP funding has been the following:

	2014	2015	2016	2017	2018	2019
C3PFP	€ -	€ -	€ -	€ 13 850 000	€ 13 850 000	€ 14 500 000

Further, the support of the Czech Republic has to be complemented at the national level by general tools to support certain activities of Czech industry and academia, especially R&D of space downstream applications in various user domains such as transport, agriculture, crisis management etc.

Operational programmes or other general support tools could also support further development of the Czech space capacities and capabilities to increase the global competitiveness of the Czech Republic (e.g. infrastructure, instrumental and technological equipment and training).

Measures:

(23) To stabilise funding of C3PFP: To fulfil the role of national space programme in order to support a sustainable growth of the capacities and capabilities of the Czech industry and academia, their competitiveness and their prepared preparedness to participate in European or international programmes the C3PFP has to be funded on multiyear basis at least at the same annual funding level as today:

C3PFP	2020	2021	2022	2023	2024	2025
	€ 14 500 000	€ 14 500 000	€ 14 500 000	€ 14 500 000	€ 14 500 000	€ 14 500 000

(24) To consider establishment of a national space programme: A possibility to establish a national space programme at the national level and to create respective technical expertise and managerial competences at the level of state in the Czech Republic should be further analysed and based on the analysis the next steps should be defined and possibly implemented. Its relation with C3PFP a PRODEX programme needs to be analysed as well.

5.3.5.2 International level

5.3.5.2.1 ESA

5.3.5.2.1.1 Mandatory Activities and CSG

Analysis:

The ESA rules on geographical return helps the Czech Republic to create and incubate capacities and capabilities of its industry and academia. The existing capacities and capabilities of industry and academia of the Czech Republic are to be further developed and pushed to the appropriate space market thanks a participation of the Czech Republic in ESA Mandatory Activities and optional programmes.

In order to participate in science missions, industrial teams, to be able to acquire high added value tasks that have the promise of building new industrial capabilities, need to be prepared well in advance in various optional programmes of ESA.

ESA Science Programme is a means for Czech scientists to get involved in world-class scientific missions. However, contribution to ESA Science Programme does not ensure itself a scientific-return in most of its missions. Due to the nature of the Mandatory Activities focused on the development or use either very low or very high TRL, there is a need to keep the contribution to ESA optional programmes at appropriate level to be able to develop capacities and capabilities especially in middle TRL and from this perspective to promote the sustainable participation in ESA Mandatory Activities and ensure the balanced geo-return of the mandatory contribution of the Czech Republic to ESA.

There is apparent problem of "the valley of death" where developments started in low-TRL technology programmes are not matched with appropriate funding to reach high-TRL levels and eventually be used. This has to be controlled by coordination between all national players already from the early stages of their involvement in low-TRL activities.

The geographical return in the domain of mandatory activities is low (86 %), which is rather typical for smaller ESA Member States. The current return level despite being low is however not the critical problem, at least not from strategic point of view. The even more serious aspect is that the most attractive activities are taken by the large ESA Member States that profit from hosting the large system integrators that have accumulated the most knowledge in almost every field of space technology and are prime contractors for large missions. In their position of an architect of both the ESA Science Programme missions and of the core industrial team to implement it, they have the power to distort the market by promoting particular technologies thus promoting particular companies, often from the same ESA Member State of corporation. Other actors can only compete for what remains. With this perspective the current return level in ESA Science Programme, despite optically seems adequate (97 %), has inherent structural difficulty of being composed of number of activities that have below average added value (within space activities, which is still high added value when compared to non-space sector). The Basic Activities return is currently 54 % and it is a result of our industry not being successful in winning tenders in DPTD. This is alarming trend, not seen before, but with potentially serious consequences. By not participating in the low-TRL projects the industry is will later not be able to mature the technology in optional programmes eventually failing to apply it to missions – both in Science Programme and other programmes. The industry must be aware that DTPD is an entry point for industry to introduce new technologies to ESA world and is a perfect springboard to overcome the valley of death.

Profile of Czech contributions to Mandatory Activities has been the following:

	2014	2015	2016	2017	2018	2019
Science Progr.	€ 2 847 825	€ 5 268 158	€ 5 242 054	€ 5 292 401	€ 5 029 407	€ 5 079 914
CIIS	€ 3 269 705	€ -	€ -	€ -	€ -	€ -
Basic Activities	€ 1 267 423	€ 2 336 531	€ 2 325 321	€ 2 349 953	€ 2 234 344	€ 2 255 772
Total	**€ 7 384 953**	**€ 7 604 689**	**€ 7 567 376**	**€ 7 642 355**	**€ 7 263 752**	**€ 7 335 686**

Concerning CSG, it should be noted that it serves as common interests of all ESA Member States to enable space missions without reliance on non-European partners. This is in particular important for

ESA Member States with global power ambitions as the CSG also serves to launch military payloads that would not be launched by foreign powers. For states that does not have such ambition the contribution to CSG can be perceived as a solidarity tax. The geographical return principle guarantees that contributions of ESA Member States eventually return to contribution countries but due to both the weighting factors and nature of work being performed at CSG is of limited technological interest and it poses logistical challenges due to offshore location and language barrier. These are also the reasons for low involvement of companies from number of ESA Member States, including the Czech Republic. It took 10 years to bring number of Czech companies to CSG as visible suppliers.

Since its last overhaul undertaken 20 years ago in view of Ariane 5 exploitation, the CSG has served two new launch systems Vega and Soyuz at CSG without any major new investments. ESA proposes introduce higher yearly contributions to modernize CSG within the next 3-5 years with view of future cost reductions being gradually introduced in 2020-2029 timeframe.

Profile of Czech contributions to CSG has been the following:

CSG	2014	2015	2016	2017	2018	2019
	€ 477 866	€ 498 417	€ 490 655	€ 491 842	€ 445 972	€ 452 766

Measures:

(25) To ensure funding of ESA Mandatory Activities and CSG: There is a high probability that the contributions of ESA Member States to ESA on Mandatory Activities and CSG will increase as of 2020 at least about 10% to reflect both inflation and needs to stabilise Science Programme, Basic activities and Guiana Space Centre. The ESA Member States’ contributions are calculated on the basis of their GDP. Their shares are reviewed periodically to reflect possible changes of economic situation.

(26) To ensure the balanced geo-return of the mandatory contribution of the Czech Republic to ESA: There is a need to keep the contribution to ESA optional programmes at appropriate level to be able to develop capacities and capabilities especially in middle TRL and from this perspective to promote the sustainable participation in ESA Mandatory Activities. The appropriate level of funding of ESA optional programmes will be defined in accordance with Chapter 5.3.5.2.1.2.

5.3.5.2.1.2 Optional Programmes

a) <u>Earth Observation</u>

ESA optional programmes in EO will be restructured as of the forthcoming period 2019+. There will be 4 main pillars: Future EO, Operational EO (Copernicus 2.0), Customised EO (Earth Watch Elements: InCubed+, International Development Aid, Altius Phase E, THRUTS) and Satefy and Security (Safety and Security EO – mainly on applications, partly ground segment, exploitation platforms and technology & system demonstrators).

Technology Programmes

Analysis:

EOEP is the backbone programme of EO activities in ESA. Most of the EO missions, both scientific (Earth Explorers) and operational (Earth Watch and Sentinels), start on elements of this programme. Considering the existing involvement and potential capacities of Czech subjects, keeping and possibly increasing the level of the current contribution should be considered as a necessary base for the future. The need to increase the contribution in this programme becomes even more important with the transfer of the Copernicus space assets (Sentinel satellites) to the EU.

Since the forthcoming period will be EOEP developed into the new Future EO programme. Future EO will build on the success of EOEP and will continue on many activities started by EOEP.

Due to the very wide range of activities covered by the (EOEP / Future EO) programme, there are many opportunities for both the companies and academia, where to participate. Academia could participate in new EE mission and instruments studies, scientific mission data processing, development of new algorithms, etc. The opportunities for industrial subjects are mainly in predevelopment activities and in preparation, as a suppliers of mission components (could be joined to the calibration activities subsequently), incl. ground segment activities, development of new geoinformation products, etc.

Involvement of Czech entities is focused mainly on scientific data processing and applications development. From the technological point of view are the Czech subjects involved e.g. on the SWARM micro accelerometer development; design and manufacturing of FLEX optics or part of Biomass on-board SW. However, EOEP offers the opportunity to participate on development of new technologies and the possibility to apply experiences and practices obtained in another ESA programmes. The industrial subjects should be more focused on this field. At the same time, there is the opportunity for larger-scale involvement of academia as well, especially on science supporting initiatives and concepts of new Earth Explorers or Small Satellites missions – this is closely linked to technology development as well.

Since its objective is to develop innovative technologies and services to be further commercialised, also EarthWatch belongs to technology programmes. Its flexible framework for cooperation between ESA and industry. It enables to implement activities designed and led by industry on partner basis. The programme help technologies to overcome "valley of death".

Potential involvement of the Czech subjects on development of AI solutions for the satellite / satellite systems management seems to be very promising area.

These optional programmes are very successful in the Czech Republic. The profile of Czech contributions to them has been the following:

	2014	2015	2016	2017	2018	2019
EOEP	€ 146 800	€ 170 600	€ 187 000	€ 269 000	€ 295 400	€ 422 600
EarthWatch/ InCubed	€ 0	€ 0	€ 0	€ 315 000	€ 107 000	€ 63 000
Total	**€ 146 800**	**€ 170 600**	**€ 187 000**	**€ 584 000**	**€ 402 400**	**€ 485 600**

Measures:

(27) To increase and stabilise contribution to ESA Earth observation technology programmes: With regards to growing EO microsatellite market and growing pressure on innovative solutions, it is highly important to have a supportive tools enabling further development of the technologies for EO satellites. There is also growing number of technology related start-ups developing promising technologies, which could be used for EO (satellites or HAPS).

That´s way the investments on the tools / programmes (especially ESA programmes) focused on technology development is needed; for ESA programmes it should grow to €5 million for InCubed in the next period (since 2020) and for envelope programme (Future EO) up to €6 million for technology development for the forthcoming 6 years. Otherwise, the Czech industry won´t be able keep its current position and further develop its capacities and potential. There should be also and instrument on national level investing on EO technologies development.

Referring to wide range of opportunities for the Czech industry and academia, lessons learned so far and the expected future benefits to economy, science and society, the appropriate level of funding should be at least the following:

	2020	2021	2022	2023	2024	2025
EO technology	**€ 1 300 000**	**€ 1 300 000**	**€ 1 300 000**	**€ 1 300 000**	**€ 1 300 000**	**€ 1 300 000**

Missions

Analysis:

EO missions are developed on EOEP, several dedicated programmes, like MTG, MetOp-SG, GMES/Copernicus Space Component and some of the dedicated elements of the Earth Watch programme. Mission development begins usually at EOEP, where are developed mission concepts, risk prevention in frame of technology pre-development and finally all the development up to the phase B1. Since the beginning of B2 phase are missions developed on dedicated programmes.

To have an interesting position in further mission consortia, e.g. related on flight HW development, it is crucial to be involved on the mission development from (very) beginning, in optimal cases. In this light is participation on such kind of envelope programme very important, because it is the only tool for these kind of activities on ESA´s EO programmes.

The Czech Republic participates on the following EO missions up to these days Meteosat Third Generation, MetOp-SG, Sentinel 4, Sentinel 5, Sentinel 6, SWARM, Biomass and Flex. There is also participation on PROBA V – technology demonstrator. Czech subjects are involved on very broad range of activities from ground support equipment, like SCOE, EGSE, simulations etc. up to specialized flight HW, like cryocooling systems, optics and related fine mechanics, breadboards, electrical circuits, mechanical parts and many others.

Based on successful participations on the missions have some of the companies been able to join to huge international value chains (gate for further orders). The Czech industry is able to deliver mission components sustainably. In the light of the current trends and development of the market, should the Czech industry consolidate their position on the market / value chains and also start to develop more complex components on the platforms or instruments.

Also the direct interface of these optional programmes to the EU and EUMETSAT activities is very important from not only economical but also strategic and political point of view.

There is a huge enlargement of Copernicus satellites fleet under preparation. Since 2018 is developed 6 High Priority Candidates Missions and new generation of current Sentinels. All together could counts 12 new prototypes, resp. up to 48 new satellites incl. recurrent units. These satellites will be developed under Copernicus Space Component -4 Programme.

These ESA optional programmes are very successful in the Czech Republic. The profile of Czech contributions to them has been the following:

	2014	2015	2016	2017	2018	2019
MetOp-SG	€ 165 000	€ 227 000	€ 1 021 000	€ 292 000	€ 362 000	€ 274 000
MTG	€ 312 000	€ 377 000	€ 707 000	€ 83 000	€ 135 000	€ 236 000
GSC	€ 288 000	€ 195 000	€ 105 000	€ 49 000	€ 38 000	€ 31 000
EOEP	€ 440 400	€ 511 800	€ 561 000	€ 808 000	€ 886 200	€ 1 266 800
Total	**€ 1 205 400**	**€ 1 310 800**	**€ 2 394 000**	**€ 1 232 000**	**€ 1 421 200**	**€ 1 807 800**

MetOp-SG (EPS-SG) and MTG programmes are also covered from contributions of the Czech Republic to EUMETSAT, as given below:

	2014	2015	2016	2017	2018	2019 (draft)
MTG	€ 1 154 563	€ 1 565 713	€ 1 646 517	€ 1 580 231	€ 1 330 750	€ 1 706 070
EPS-SG PP	€ 161 103	€ 177 525	€ 17 064	€ -	€ -	€ -
EPS-SG	€ -	€ 198 011	€ 1 357 661	€ 2 436 818	€ 2 754 787	€ 2 557 566
Total	**€ 1 315 666**	**€ 1 941 249**	**€ 3 021 242**	**€ 4 017 049**	**€ 4 085 537**	**€ 4 263 636**

Note: these figures don't represent the full scale of Czech Republic's contributions to EUMETSAT, the other budget items not included here are the GB (General Budget), EPS, and MSG programmes.)

Measures:

(28) To increase and stabilise contribution to ESA Earth observation missions: On the basis of the capacities already built and experiences they´ve (industry) got on the mission development, is the industry ready for participation on development of the future missions and for getting of new orders not only on growing segment of institutional mission, but also on rapidly growing commercial mission segment. The Czech Republic should keep its position on the mission development and should ensure the tools for the industry, which will enable their participation. The participation on the new institutional scientific and application mission will pave the way for higher involvement on the commercial market. That´s why the Czech Republic have to invest on the mission development programmes covering all the development chain. It means envelope programme (EOEP or its successor) and dedicated mission development programmes, Copernicus Space Component in particular (but not only). Referring to the overall benefits of described missions, lessons learned so far and the expected future benefits to economy, science and society, the appropriate level of funding should be at least the following:

EO missions	2020	2021	2022	2023	2024	2025
	€ 3 500 000	**€ 3 500 000**	**€ 3 500 000**	**€ 3 500 000**	**€ 3 500 000**	**€ 3 500 000**

Applications

Analysis

EO based applications and services is a rapidly growing sector. It is highly boosted by Sentinels and also by the upcoming small private or institutional missions. There are two major causes of rapidly growing number of users. The first is much more and cheaper EO data available. Because of the data policy are the Sentinels (Copernicus programme) the real game changer. The second is growing performance of ICT, which enables processing and distribution of such high amount of data.

Users starts to feel EO data as one of the standard (primary) data sources. There is also higher awareness about the potential of EO data in comparison with the previous period (2014-2019) and more experts, which are able to process the data into products / applications. Same importance for mass expansion of EO data use has computing platforms – national / regional / thematic and others. These platforms brings not only data but primarily information to the users. Most of the users are not EO data processing experts (and the don´t want to be). That is why the platforms starting to play more and more important role. Amateurisation of EO is one the strongest trends on this domain. There is positive experience and user feedback for Sentinel Collaborative Ground Segment Platform, currently (2019) operated by CESNET. The platform is used for both data download and for computing of the products on the site.

Under the initiative of the European Commission has been developed a several Data and Information Access Service (DIAS) platforms, which also starts to find their users.

Because of the specialized ESA tools (envelope programme and InCubed) starts the Czech industry and other subjects develop applications with huge potential. The applications are focused on the agriculture, atmosphere monitoring, urban development, infrastructure monitoring and other segments. There is a few companies with huge potential reach European scale / global scale success and penetrate mass market with their products. For the “EO downstream” companies starts to be crucial have capacities and capabilities on ICT domain.

Rapidly developed technologies, like artificial intelligence and blockchain could bring new opportunities for EO data processing and for modelling of the products directly for the respective customers. ESA shapes it´s tools to be supportive on further EO application development, using new technologies. These kind of tools enables Czech industry, academia and governmental organizations keep their position on the market and via development of the new solutions also continue on penetration of new markets. ESA BIC, ESERO, Copernicus Relays and Copernicus Academy helps a lot with the awareness rising about EO data and products among the users.

The profile of Czech contributions to the relevant optional programmes has been the following:

	2014	2015	2016	2017	2018	2019
EOEP	€ 146 800	€ 170 600	€ 187 000	€ 269 000	€ 295 400	€ 422 600
EarthWatch/ InCubed	€ 0	€ 0	€ 0	€ 315 000	€ 107 000	€ 63 000
Total	**€ 146 800**	**€ 170 600**	**€ 187 000**	**€ 584 000**	**€ 402 400**	**€ 485 600**

Measures:

(29) To increase and stabilise contribution to ESA Earth observation applications programmes: The Czech Republic should focus on further development of capacities and capabilities of industry and academia in the field of EO data use and applications and EO data processing (incl. scientific data). Because of the rapidly growing market and coming new data processing technologies, there have to be supportive tools for adaptation on the changes of paradigm in EO. The supportive tools should be focused in particular on AI data processing, cloud computation and big data processing, support of scientific excellence in EO, bridging between science and applications, development of new applications and innovative solutions, ensure the scheme for transfer of the promising ideas into the reality / practice, incl. small grant scheme. Most of these activities should cover the EOEP successor Future EO Programme on which the Czech Republic should invest. The Czech Republic have to invest into the envelope programme and suitable EarthWatch elemets, mainly InCubed+. With regards to importance of EO platforms for "translation" of the EO data into information readable for EO non-expert users, importance of EO data and products dissemination and for calculation of new EO based products for the purposes of very broad user community, the Sentinel Collaborative Ground Segment initiative should be further supported and developed. A specialized EO computational centre should be established and developed for the purposes of the specific governmental needs. The appropriate level of funding should be at least the following:

	2020	2021	2022	2023	2024	2025
EO applications	**€ 1 100 000**	**€ 1 100 000**	**€ 1 100 000**	**€ 1 100 000**	**€ 1 100 000**	**€ 1 100 000**

b) Telecommunications

Technology Programmes

Analysis:

ARTES technology programmes form the backbone of ESA SatCom activities and traditionally cover the majority of all ESA SatCom activities, as far as budget is concerned. The technology developments start at TRL 1 in ARTES Future Preparation programme (FP). The subscription to FP is mandatory for all ARTES participating states, because this programme literally underpins the whole ARTES.

The overwhelming majority of ARTES technology developments takes place in ARTES Core Competitiveness. The ESA initiated Advanced Technology element (ARTES AT) offers Czech companies a workplan with about 50 ITTs every year for all aspects of SatCom systems' space and ground segment including platform system and architecture, propulsion, thermal, power and AOCS systems, antennas, repeaters and ground segment equipment including user terminals. This workplan is established based on the results of an annual Call for Ideas open to member states' industries. This Call is therefore instrumental in creating the right opportunities for the Czech industry, since the companies themselves can prepare the territory for future ITTs.

As the ARTES AT offers to Czech entities to engage in the earlier stages of SatCom development, the maturity of these developments can be furthered in the frame of industry initiated Competitiveness & Growth element (ARTES C&G), leading to a pre-commercial product stages (TRL 7-8). ARTES C&G is of a strategic interest to Czech Republic, because it serves as a bottom-up funding tool for ad-hoc technological developments of Czech industry with a potential of commercialisation, primarily, but not exclusively, at the SatCom market. ARTES C&G is also a catalyst for private investment, since the projects in C&G are co-funded by industry usually at 50 % level. According to the ESA's analysis of 71 industry contracts worth €180 million, the average return of investment of a C&G activity is 2,49. The whole ARTES Core Competitiveness programme is raising an interest among Czech industry slowly, but steadily.

One technology domain is being developed in a dedicated element called ARTES Scylight. The Scylight programme enables Czech industry and academia to participate in R&D leading to new optical communication systems, especially to apply a unique know-how in the field of quantum cryptography. Under ARTES 4.0 the Scylight programme will be implemented in the form of a Strategic Program Line Optical Communication – Scylight.

The profile of Czech contributions to the relevant optional programmes has been the following:

	2014	2015	2016	2017	2018	2019
Future Preparation	€ 27 883	€ 42 000	€ 16 000	€ 189 301	€ 9 940	€ 7 000
Core Competitiveness	€ 246 000	€ 282 000	€ 2 673 865	€ 2 834 000	€ 2 250 000	€ 3 275 000
ScyLight	€ -	€ -	€ -	€ 1 414 000	€ 146 000	€ 196 000
Total	**€ 273 883**	**€ 324 000**	**€ 2 689 865**	**€ 4 437 301**	**€ 2 405 940**	**€ 3 478 000**

Measures:

(30) To increase and stabilise contribution to ESA telecommunication technology programmes: With a guaranteed geographical return coefficient 1 of ARTES Core Competitiveness in mind, with respect to the wide range of opportunities for the Czech industry and academia, lessons learned and the expected future benefits to national economy, science and society, the appropriate level of funding should be at least €4 million per year for SatCom technology programmes within ARTES 4.0. Without an increase of funding, the Czech Republic could miss the opportunity to boost disruptive technologies, New Space opportunities including new mega-constellations to serve the new SatCom market demands, foster the sustainability of SatCom industry and trigger larger private investment delivering higher socio-economic impact. The Czech Republic should also join the new ARTES 4.0 Strategic Programme Line Optical Communication - Scylight. The appropriate level of funding should be at least the following:

SatCom	2020	2021	2022	2023	2024	2025
technology	€ 3 300 000	€ 3 300 000	€ 3 300 000	€ 3 300 000	€ 3 300 000	€ 3 300 000

Missions

Analysis:

The ARTES mission programmes have a goal to develop and demonstrate new SatCom operational systems, which can be new types of SatCom satellite platforms, satellite systems consisting of new dedicated SatCom satellites or hosted payloads on board commercially available GEO platforms, including innovative ground segment. The ARTES mission programmes are often undertaken in public private partnership (PPP) with a satellite system integrator, which proposes innovative product line with or without industrial supply chain and with or without a business case based on expected product sales. The private partner can be also a commercial satellite operator (including New Space) and users for testing and validation of immature new technology and services from technical or market standpoint, in which case the programme contains a long-term business case for validation and exploitation. ARTES contains more than 20 such programmes, implemented as standalone ARTES elements, sub-elements or individual projects and new ones are under preparation.

The Czech Republic currently participates in four such programmes: Neosat, Iris, EDRS Global and Govsatcom Precursor. The Neosat programme has been very successful and it will be completed in 2020. Therefore no more new project opportunities are expected in this programme. Neosat enabled involvement of several Czech companies into the supply chains of traditional European satellite system integrators – Airbus Defence & Space and Thales Alenia Space – with qualified products.

The Czech Republic has of a long-term interest in Iris programme and many developmental steps have already taken place during the last 10 years in previous phases of Iris programme. The final product of Czech contribution will be a commercially available SatCom user terminal for civil aviation, certified for the use in the EU under the umbrella of a Single European Sky. The Iris programme already enabled the development of a prototype of the user terminal and strengthened the position of Czech industry at European level. In the current and next phase, the terminal should be finalised and tested in pre-operational and operational system setting with commercial airliners. In ARTES 4.0 the Iris programme will be implemented in the frame of a Strategic Programme Line Secure SatCom for Safety and Security (4S).

So far, the Czech Republic's contribution into EDRS Global (formerly called as Globenet) enabled the involvement of Czech industry into the security segment of the globally scaled up EDRS system. A potential follow-up of current activities might be envisaged, if the ongoing engagement of Czech industry proofs to be successful and beneficial both for the EDRS system and national economy. In ARTES 4.0 the system EDRS Global will be implemented in the frame of Strategic Program Line Secure SatCom for Safety and Security – 4S.

The activities in Govsatcom Precursor, which were originally planned for Czech participation, had to be abandoned due to various complexities and very challenging project timeline of the system prime. It is very likely that under ARTES 4.0 the Govsatcom Precursor programme will be implemented in the form of a broader horizontal Theme 4S – Secure SatCom for Safety and Security and the Czech Republic will continue to monitor the new opportunities. As it was mentioned earlier, the Czech Republic also subscribed to ARTES ICE, but because the ARTES ICE Phase 2 was closed by ESA due to unexpected change of plans of the Inmarsat as system prime and there were no more opportunities for Czech industry, the bulk of Czech contribution was transferred to ARTES IAP programme in 2018.

Moreover the Czech Republic also observes a number of opportunities in other ARTES mission programmes, which are already ongoing, but so far without Czech participation, namely the ARTES Sat-AIS – Sub-element 2B (specifically the project Triton-X) and ARTES Partner – Sub-element QKD Sat. The QKD Sat is a mission demonstrator of satellite based quantum key distribution system in partnerships with satellite operator. The Czech Republic transferred €1 million into QKD Sat from ARTES Core Competitiveness.

In the frame of ARTES Sat-AIS Sub-element 2B, the Czech Republic sees a promising potential in project Triton-X. The Triton-X offers a possibility to bring on board a larger group of Czech industry into a satellite manufacturing supply chain with a prospect of serial production. The project also promises a variety of innovative space qualified hardware developments, with a fast to market development pace, in the New Space spirit. Based on discussion with the OHB LuxSpace, the Czech Republic transferred €2.9 million into ARTES Sat-AIS - Subelement 2B from ARTES Core Competitiveness to rapidly cover the most critical, with a possibility of later increase by circa €2 million or more at the ESA Council at ministerial level. Last, but not least, the project also offers an opportunity to strengthen current positive political relations between Czech Republic and Luxembourg, which were underpinned by a bilateral intergovernmental agreement signed in 2018.

The Secured SatCom for Safety and Security (4S) will be a Theme in ARTES 4.0, which intends to collect versatile ideas and projects with a common goal of increasing the security of SatCom driven by the need to adopt high levels of cyber-security and respond to cyber-warfare. It is a container, which offers member states to allocate a bulk of funding with that specific goal in mind, without necessarily knowing all the details and concrete projects, into which to put the money right away, although a concrete allocation into projects is also possible. It is a strategic funding container. There are several projects, which will fall under the new Strategic Program Line 4S: Govsatcom Precursor, Iris Global Satcom Solution and SAGA. Czech Republic perceives the security element of SatCom as a strategic advantage and a must for future SatCom systems. Czech Republic currently financially participates in the ARTES Iris, Govsatcom Precursor and EDRS. The Czech Republic should sustain its participation in the Iris programme, which has a strategic value for the Czech aerospace industry, as well to seek new opportunities in EDRS Global and Govsatcom Precursor. Joining the new SAGA project is highly recommended, since it will be a precursor of a future EU Quantum Communication Infrastructure. Therefore, the Czech Republic should be also part of the overall 4S Strategic Programme Line.

The Optical Communication – Scylight Strategic Program Line will contain the strategic elements of optical communication including common system and critical technologies, optical communication and quantum technologies and applications and projects developing demonstration missions, such as HydRON . The Czech Republic understands optical communication as the technological solution for the ever-growing demand for high volumes of data and constant connectivity anytime and everywhere. Czech Republic currently participates in the ARTES Scylight, which focuses on the exact same topic. However, the HydRON and Saga projects intend to demonstrate complete operational systems, which goes one step above the current scope of Scylight. To explore suitable opportunities for participation of Czech Republic in HydRON is also recommended.

Apart from the Strategic Program Lines mentioned above, we expect that other opportunities might appear later in the Strategic Program Line Satellite for 5G (S45G also known as Mercury), eg. project Novacom. Under this initiative, vertical market trials of integrating 5G SatCom technologies into terrestrial 5G networks will be demonstrated. To explore suitable opportunities for participation of Czech Republic in S45G is also recommended.

The profile of Czech contributions to the relevant optional programmes has been the following:

	2014	2015	2016	2017	2018	2019
Iris	€ 103 000	€ 83 525	€ 10 000	€ 1 619 000	€ 1 671 366	€ 1 695 000
Neosat	€ 240 000	€ 314 000	€ 293 000	€ 429 000	€ 1 081 000	€ 811 000
PPP GovSat	€ -	€ -	€ -	€ 455 000	€ 221 000	€ 463 000
EDRS Globenet	€ -	€ -	€ -	€ -	€ 674 000	€ 198 000
ICE	€ -	€ -	€ -	€ -	€ 637 000	€ -
Total	**€ 343 000**	**€ 397 525**	**€ 303 000**	**€ 2 503 000**	**€ 4 284 366**	**€ 3 167 000**

Measures:

(31) To increase and stabilise contribution to ESA telecommunication missions: Specifically in the Iris Global SatCom Solutions programme, taking into account the long-term plan of Czech industry and the system prime until 2023, we expect that an annual budget of €1 million will be required to cover ongoing and future activities. Additional €1 million is envisaged for the potential EDRS Global activities and new opportunities in Govsatcom Precursor. The Triton-X project alone contains a potential need for allocation of €5 million. In case of Neosat programme, no additional measures are required, because the programme will be finished soon. New opportunities, however, are expected in the QKD Sat and new programme activities in the frame of ARTES 4.0 programme container in Strategic Program Lines Optical Communication – Scylight (eg. project HydRON), Secured SatCom for Safety and Security 4S (eg. project SAGA) or even Satellite for 5G (S45G also known as Mercury, eg. project Novacom). It needs to be stressed, that many of the opportunities will manifest only in the course of the programmes and cannot be fully predicted in advance. Therefore, the Czech Republic needs to keep a high level of flexibility. Referring to the overall societal benefits of described missions, the industrial technological excellence and the expected future benefits to national economy through established supply chains, the appropriate level of overall funding should be at least €4 million per year, to cover ongoing projects and also the future opportunities:

SatCom missions	2020	2021	2022	2023	2024	2025
	€ 2 500 000	**€ 2 500 000**	**€ 2 500 000**	**€ 2 500 000**	**€ 2 500 000**	**€ 2 500 000**

Applications

Analysis:

Most of the SatCom applications in ARTES are developed in the frame of Integrated Applications Promotion programme (IAP), which will transform into new Business Applications-Space Solutions programme (BASS). The IAP/BASS offers many project opportunities from a variety of space applications domains, including those outside the scope of SatCom. The IAP/BASS can also support development of applications and downstream services in Earth observation, satellite navigation, even human spaceflight and their mutual combinations. Therefore, the IAP/BASS belongs to the more popular programmatic tools amongst Czech companies, especially SMEs and star-ups, because it requires little or no previous space heritage from them. Several projects have been under implementation in the area of UAVs utilization for surveillance and tourism, agriculture, management of airports. The IAP/BASS programme also holds the budget line for Ambassador Platform, which is a tool of potential interest for Czech Republic. The Ambassador Platform could facilitate the engagement of new industrial companies including SMEs into space applications by creating awareness, providing consultation services and mentoring. Potentially, it could do the same for the industries developing new technologies in ARTES Core Competitiveness. The IAP/BASS programme can also support the development of new Czech companies, which will finish their incubation period in ESA BIC Prague or other national start-up funding tools. The BASS programme will be also responsible for the ESA BIC and Technology Transfer Broker activities. This programme is quite unique in ESA, since there has been implemented no other downstream oriented support programme of such a scale in the agency before and it will bring clear and direct benefits to Czech Republic. The IAP/BASS programme is open for subscriptions in 3-4 year cycles at each ESA Council at ministerial level and the profile of Czech contribution has been the following:

	2014	2015	2016	2017	2018	2019
IAP	**€ 175 000**	**€ 173 622**	**€ 86 000**	**€ 264 000**	**€ 219 000**	**€ 248 000**

Measures:

(32) To increase and stabilise contribution to ESA applications programmes: Referring to wide range of opportunities for the Czech industry, lessons learned so far and the expected future benefits to economy and society, the appropriate level of funding into applications should be at least the following:

	2020	2021	2022	2023	2024	2025
Applications	**1 400 000 €**	**1 400 000 €**	**1 400 000 €**	**1 400 000 €**	**1 400 000 €**	**1 400 000 €**

c) Satellite navigation

Analysis:

There are two kinds of opportunities available in the satellite navigation activities domain under ESA's scrutiny. The first group are self-standing activities implemented in ESA's optional programme NAVISP (Navigation Innovation and Support Programme) and European GNSS Evolution Programme (EGEP), the second part are activities related to development and operation of Galileo and EGNOS (together called EGNSS programme). The EGNSS activities, although managed by ESA, are funded from the EU's Horizon 2020 and GNSS Regulation budgets and do not obey the ESA Convention, e.g. the rules of a geographical return. In the previous years, EGEP enabled a number of diverse projects dealing with GNSS spoofing robustness, EGNOS V3, optical time transfer links, tropospheric modelling, GNSS data mining etc. All the projects with Czech participation have finished and the programme will be closed soon. Therefore, all future opportunities reside in the NAVISP programme. Projects dealing with train location and control using GNSS in the frame of ERTMS have been implemented so far and one project dealing with GNSS vulnerability analysis is under implementation. The Czech Republic very much appreciates the unique tool of NAVISP element 3, which can support the GNSS/PNT activities of national interest. We also expect the interest to increase in both element 1 and 2 from the industry side.

The profile of Czech contributions to the relevant optional programmes has been the following:

	2014	2015	2016	2017	2018	2019
EGEP	€ 241 000	€ 98 000	€ 51 000	€ 33 000	€ 6 000	€ 3 716
NAVISP	€ -	€ -	€ -	€ 2 027 000	€ 56 000	€ 75 000
Total	**€ 241 000**	**€ 98 000**	**€ 51 000**	**€ 2 060 000**	**€ 62 000**	**€ 78 716**

Measures:

(33) To increase and stabilise contribution to ESA's satellite navigation programme: Referring to the opportunities for the Czech industry and academia, the strategic national interests in PNT and the expected future benefits to national economy, science and society, the appropriate level of funding should be at least the following:

	2020	2021	2022	2023	2024	2025
SatNav	**€ 800 000**	**€ 800 000**	**€ 800 000**	**€ 800 000**	**€ 800 000**	**€ 800 000**

d) General technology

Analysis:

The GSTP programme plays essential role in turning a promising technology to a qualified product. In addition, it is a tool for doing this in an international cooperation which is essential for Czech industry given many Czech products are being developed in close partnerships with foreign companies. For this reason, the GSTP must be a complementary counterpart of the national space programme or C3PFP.

With the introduction of C3PFP, the interest in the GSTP programme declined, because C3PFP is perceived by industry as having more attractive conditions (level of co-funding, offer evaluation time, less competition) than the GSTP. Still, we propose to re-inforce the programme funding correspondingly to changes in C3PFP.

This optional programme is very successful in the Czech Republic. The profile of Czech contribution to it has been the following:

GSTP	2014	2015	2016	2017	2018	2019
	€ 961 000	€ 916 000	€ 833 000	€ 2 082 000	€ 3 418 000	€ 3 302 000

Measures:

(34) To increase and stabilise contribution to ESA general technology programmes: Referring to wide range of opportunities for the Czech industry and academia, lessons learned so far and the expected future benefits to economy, science and society, the appropriate level of funding should be at least the following:

General Technologies	2020	2021	2022	2023	2024	2025
	€ 4 200 000	€ 4 200 000	€ 4 200 000	€ 4 200 000	€ 4 200 000	€ 4 200 000

The C3PFP conditions needs to be revisited and possibly adjusted to the level of ESA programmes.

e) Launchers

Technology programmes

Analysis:

The FLPP programme is a gateway to development programmes of ESA launchers. Many technologies will be used in Ariane and Vega evolutions as well as in new generations of launcher – both European and foreign, both institutionally and privately funded.

The Czech Republic had joined the programme by subscribing of €0.5 million in 2008 and €1 million in 2012 and since 2017 there is additional €4 million added. All these subscriptions were only sufficient for few projects with rather low TRL levels. This was in strong contrast with the actual interest of Czech companies in the programme that was in many cases backed by strong support of Ariane and Vega development teams. It has been repeatedly experienced that the subscription level is too low and limiting the companies to grow. Additional subscription would be needed to reach higher TRL levels and to penetrate supplier chains with qualified products. For the Czech Republic, it is favourable – both technically and economically – to support development of technologies that can be used across whole portfolio of launchers – the Ariane and Vega to start with but not being limited with the two, expanding to micro launchers, non-ESA-developed small, medium and heavy launchers and seeking applications of the technologies beyond launcher industry.

New programmatic frames are being elaborated by ESA as a preparation for Space19+. It is not yet clear whether these will take for of new programmes or will be pursued as continuation of FLPP, however the programmatic nature is FLPP-like as these are basically complex demonstrators with associated technology maturation. In particular, the key seems to be the Ariane low-cost / lightweight upper stage (composite “Black Stage”), Vega C++ new upper stage and reusability demonstrator with Prometheus engine. On top of it ESA is willing, as of Space19+, to support commercial-driven and national-driven developments of micro launchers.

This optional programme is very successful in the Czech Republic. The profile of Czech contributions to it has been the following:

	2014	2015	2016	2017	2018	2019
FLPP	€ 479 000	€ 443 000	€ 709 000	€ 580 052	€ 1 319 000	€ 1 211 000

Measures:

(35) To increase and stabilise contribution to ESA launcher technology programmes: The demand for projects from industry and academia exceeds the available resources, but launcher projects (if successful) can bring large long-term financial benefits and strongly increase competitiveness of Czech industry and thus secure its financial stability and sustainability. Based on historical experience, it is strongly recommended to at least double FLPP subscription allowing for completion of the already initiated activities and adopt new activities for which funding was not available in 2017-2019 time frame. Further, there is a need to subscribe to Ariane and Vega evolution programmes €9.5 million annually combined (being consistent with current AVD spending and at the same time double the proposed FLPP subscription reflecting higher cost in productization phase of development as compared to technology development), to allow to new entrants to penetrate the supplier chains of launchers with qualified products.

Launcher technology	2020	2021	2022	2023	2024	2025
	€ 2 800 000	€ 2 800 000	€ 2 800 000	€ 2 800 000	€ 2 800 000	€ 2 800 000

Missions

Analysis:

The AVD programme is running full speed towards the maiden flights of Ariane 6 and Vega-C. Delays are under control and both launchers are likely to become operational rather soon. Major issue is the change in the space transportation market, notably in GTO sector due to serious decline in SatCom orders as a consequence of overall slump in the telecom domain, non-GTO megaconstellation hype and boom of terrestrial infrastructures (fibre). This decline will have negative impact of production rump-up and exploitation revenues. The cost control will be more important than ever, as there is no real backup for Ariane 6 at the moment (except for Ariane 5, whose contract is expiring).

ESA has planes for competitiveness improvement programmes to be introduced at Space19+ – both for Ariane 6 and Vega-C as well as for their common element, the P120C booster.

Due to the decline of launch rate, notably from commercial sector the industry will have to renegotiate the exploitation conditions giving ESA chance to re-evaluate the governance shift towards industry and re-gaining visibility, if not control, over the industrial setup, flows, costs, etc. For member states this is likely to have a cost of (1) higher price per unit when purchasing institutional missions, (2) danger of service provider losses due to competitiveness at the commercial market and (3) worse return on investment as a result of lower cadence. Due to low impact on rump-up, a higher cost of transition programme or support to exploitation is not foreseen, however the competitiveness improvement programme of ESA is still pertinent and possibly even more so than foreseen at the time of CM14. European Institutional Exploitation (EIE) driven approach to mitigation of the unfavourable market situation is likely the best mitigation of risk of lost access to space and loss of expertise.

As far as SpaceRider development is concerned, ESA continues to promote it, but its business case remains uncertain.

	2014	2015	2016	2017	2018	2019
AVD	€ -	€ -	€ 820 000	€ 7 064 000	€ 9 442 657	€ 7 838 000

Measures:

(36) To increase and stabilise contribution to ESA launcher missions: Despite the current slump in the launch service demand, the space transportation remains recurrent business with future potential. The pace with which the developments will continue under current situation is unpredictable, hence cautious approach is advised. There will be need to contribute to Ariane and Vega competitiveness improvement programmes but with unknown dynamics of these programmes it might be wise to spread the funds between the competitiveness improvement programmes (mission-like) and future technology programme (technology-like) from which funds might be transferred to mission-like programme relatively easily. The cost associated with EIE-driven exploitation approach, for the planning purposes, should be included in the mission-type programme of D/STS because little is known about the actual funding needs.

Further consideration is related to evolution of FLPP technology project that will in 2020-2025 reach the TRL allowing them to be applied in particular launchers development programmes. This would require substantial investment.

It is therefore recommended to invest to mission-like programmes i.e. follow-ups of AVD programme €20 million with the proviso, that part of this fund might be temporarily allocated to technology-like programme if the situation at Space19+ will not be readable.

Launcher missions	2020	2021	2022	2023	2024	2025
	€ 9 500 000	€ 9 500 000	€ 9 500 000	€ 9 500 000	€ 9 500 000	€ 9 500 000

f) Human Space Flights, Microgravity and Exploration

Analysis:

The Czech Republic is currently over-return in the programme, however the technical work performed is not directly linked to scientific interests in Czech academia, which would be desirable in science-focused programme. The user community i.e. scientists active in the exploration or microgravity is very limited in the Czech Republic.

Apart from ISS and LOP-G, the E3P programme contain wide range of technological projects – some with very low return-on-investment potential and some with rather high one. Further support to the programme and exploration missions in general should be made if and only if specific high- return-on-investment technologies are identified well in advance the subscription hand in hand with programme management. On average and at the lowest level of industrial chain the E3P activities have arguably the smallest return on investment of all optional programmes. For this economic reason the subscription should be kept minimal for the next subscription period.

Apart from preparation of human exploration of space and fundamental research, in both physical and life sciences the programme also contributes to applied research and industry-driven R&D, development of advanced technologies to support the optimum utilization of ISS and future space infrastructures and last but not least to educational and outreach activities exploiting the ISS and using the European astronauts as ambassadors of science and technology, which has strong impact on public – both general and in particular youth.

The exploration projects can also serve as technology demonstrators and means to gain flight heritage to be exploited in other, even non-ESA missions. This may be currently the case for the e-pump technology developed in the Czech Republic.

For the two latter reasons the subscription should be kept non-zero. The profile of Czech contributions to the relevant optional programmes has been the following:

	2014	2015	2016	2017	2018	2019
ELIPS	€ 279 000	€ 243 000	€ 162 000	€ 91 000	€ 35 000	€ -
ETHE	€ 685	€ -	€ -	€ -	€ -	€ -
Aurora MREP	€ 133 000	€ 102 000	€ 176 000	€ 161 000	€ 125 795	€ 28 000
E3P Period 1	€ -	€ -	€ -	€ 321 000	€ 502 000	€ 457 000
Total	**€ 412 685**	**€ 345 000**	**€ 338 000**	**€ 573 000**	**€ 662 795**	**€ 485 000**

Measures:

(37) To carefully analyse the opportunities for academia-industry synergetic projects and to subscribe accordingly, even minimize the subscription due to generally low return-on-investment, however leave provision for exploitation of the attractiveness of the programme for outreach:

E3P	2020	2021	2022	2023	2024	2025
	€ 500 000	**€ 500 000**	**€ 500 000**	**€ 500 000**	**€ 500 000**	**€ 500 000**

g) Space Safety and Security

Space Safety

Analysis:

SSA programme is an optional programme designed to cover the area of Space Safety. The SSA programme is effective for 2009-2020 and is slowly reaching the end of its operational phase. Czech Industry and Academia both actively participate in SSA programme, as well as in other European/international initiatives related to the SSA. The involvement of Czech academia and industry in all three SSA domains (also incl. SWE Lagrange Mission activities) is well established and leading to an increase of expertise of involved entities.

The Czech Republic has invested €700 000 for SSA P2 (2012-2016) and €2 million for SSA P3 (2017-2020). These contributions were (in case of SSA P2 and according to the current plans for SSA P3) mostly used.

The profile of Czech contribution to it has been the following:

	2014	2015	2016	2017	2018	2019
SSA	**€ 135 000**	**€ 198 000**	**€ 169 000**	**€ 402 970**	**€ 455 000**	**€ 546 000**

The SSA programme will be replaced by a Space Safety Programme (SSP) from 2020. The SSP, with its main goal to protect our planet, humanity, and assets in space and on Earth from threats originating in space, will continue in current SSA activities and will complement them with a number of new technological and scientific activities related to the Asteroid Deflection Demonstration, In-Orbit Servicing, Active Debris Removal, Autonomous Satellite Collision Avoidance etc.

Measures:

With respect to seamless drawing of SSA programme contribution and broader list of activities that will be carried out by the SSP programme, an appropriate increase of funds is required. The absorption capacity of the Czech industry and academia in the area of Space Safety is approx. sevenfold compared to SSA 2019.

The knowledge gained through HERA mission and its respective CubeSats will be valuable assets in future small spacecraft planetary exploration, space resource utilization missions and planetary defence. The expertise includes proximity operations in the low-gravity environment as well as critical instruments for the exploration of the objects' chemical and physical properties. Such capabilities have value from scientific perspective, as asteroids store unique information about the origins of the Solar System, security perspective, as knowledge of porosity and mineralogy are required to determine deflection methods of potential objects on the collision course towards the Earth, and of economic perspective, as asteroids are sources of extremely valuable minerals.

(38) To increase and stabilise contribution to SSA/SSP programme: Referring to wide range of opportunities for the Czech industry and academia, lessons learned so far and the expected future benefits to economy, science and society, the appropriate level of funding should be at least the following:

Space Safety	2020	2021	2022	2023	2024	2025
Programmes	€ 3 500 000	€ 3 500 000	€ 3 500 000	€ 3 500 000	€ 3 500 000	€ 3 500 000

Space Security

Analysis:

There is no single ESA programme designed to cover Space Security and its applications – Space Security pervades a number of other programmes and domains like EO, SatCom, NAV, IAP and SSA/SSP and complements them with a series of specific tasks and activities. From national perspective, the Space Security represents opportunities in the area of quantum cryptography and blockchain applications.

Specifically in the SatCom domain, ESA will launch a new Theme – Secured SatCom for Safety and Security (4S) in ARTES 4.0 programme, which intends to collect versatile ideas and projects with a common goal of increasing the security of SatCom driven by the need to adopt high levels of cyber-security and respond to cyber-warfare. Security related technologies and systems will also be developed in the Theme – Optical Communication, including quantum cryptography technologies, such as Saga mission, which aims at development of European quantum key distribution network precursor. The project responds to a vision of a pan-European quantum communication network, which is under discussion in the frame of EU Digital Europe Programme – Cybersecurity and Trust element.

Measures:

(39) To Strengthen the dialogue with ESA and its Member States especially in order to ensure the protection of present and future Europe's space assets; support Space Security activities with high added value and a potential of involvement of Czech industry and academia. Space Security plays a critical role in securing the benefits of space activities and applications. This area is very important despite the fact that there is no specific programme related to Space Security. Regarding the 4S and Optical Communication programmes, Czech Republic observes opportunities both in currently running programmes (Iris, EDRS Global) and the new opportunities in ARTES 4.0, namely QKD Sat and Saga. More details including numbers can be found in this Chapter with analysis and measures for ESA telecommunication programmes.

h) Scientific Payload

Analysis:

The main tool to support scientific payload projects and also to ensure scientific-return (access to scientific data) from ESA's Science Programme missions is PRODEX. PRODEX can be used also on participation in missions outside ESA. It is the most popular ESA programme among the Czech scientists as it is their prime vehicle to participate in missions of ESA Science Programme. Budget of the programme is used to develop hardware and software for instruments and such contributions allow the Czech scientists to claim their position in instrument science teams, which grants them an early access to scientific data.

Companies enjoy little competition in the programmes (tenders are restricted to the Czech Republic) which seems favourable to them in short-term because earning contracts is much easier than in pan-European competition. It is needed to assess innovation potential of such contracts. Long-term focus of companies to less competitive tenders combined with low innovation potential can negatively affect their competitiveness in long-run and as a consequence depreciate interests of Czech Republic in space activities (i.e. competitiveness and economic growth).

On the contrary PRODEX can be used as a tool to implement industrial policy by encouraging scientists to seek, during consortia formation processes, opportunities to earn technically interesting work share that is both stimulating the involved scientific team and challenging for the Czech industry. Additionally instruments funded by PRODEX might be good opportunities to demonstrate qualified technologies and gain the much sought-after flight heritage.

The Czech Republic has such an ambition to make an impact on international scene and therefore the funding has to be increased. Financial resources of PRODEX programme should be primarily used to develop and operate scientific payloads (HW and SW) while data analysis funding should be obtained from the non-space national R&D funding sources, if possible.

PRODEX can be also used to fund some ambitious projects which NSP proposes.

The profile of Czech contribution to PRODEX has been the following:

	2014	2015	2016	2017	2018	2019
PRODEX	**1 500 000 €**	**1 500 000 €**	**1 500 000 €**	**2 200 000 €**	**2 200 000 €**	**2 200 000 €**

Measures:

(40) To increase and stabilise contribution to PRODEX: Referring to wide range of opportunities for the Czech industry and academia, lessons learned so far and the expected future benefits to economy, science and society, the appropriate level of funding should be at least the following, taking into consideration that PRODEX can also be used as an industrial policy tool to gain flight heritage for particular technologies:

	2020	2021	2022	2023	2024	2025
PRODEX	**3 200 000 €**	**3 200 000 €**	**3 200 000 €**	**3 200 000 €**	**3 200 000 €**	**3 200 000 €**

Note: ESA Mandatory Activities, CSG and E3P should be funded by MŠMT. EO missions, Space Safety Programme and PRODEX should be co-funded by MD and MŠMT. Other ESA optional programmes and C3PFP should be funded by MD. The closest such ESA Council at ministerial level will occur in November 2019, the following ones are anticipated at the end of 2022 and 2025. Given that the above ESA optional programme funding proposals always stem from the current understanding of the situation, in the process of programme implementation it may rise the need to (1) adjust distribution of funds among programmes or (2) fund new ESA optional programme initiated in reaction to market changes. Considering that between ESA Councils at ministerial level it is usually not possible to efficiently secure new funding, delegation of the Czech Republic to ESA must, in justified cases and in line with the NSP, implement the reallocation of funds between ESA optional programmes. It is only this flexibility that allows efficient management of public funds invested in ESA.

5.3.5.2.2 EU

<u>Copernicus</u>

Analysis

The Czech participation on Copernicus programme consists of participation on the building of the satellites and on usage of Copernicus services and data. With growing number of Sentinels on the orbit, growing amount and sorts of data is gradually growing also the number of data and service users.

Concerning Sentinel data, the number of users is constantly growing. There is more than 200 000 users registered on Sentinel Data Hub and more than 150 users on National Collaborative Ground Segment (2019).

From the current core services is mostly used the Copernicus Land Monitoring Service (because of agriculture, land user / land cover and other applications in frame of the service). The Emergency response service is activated by Fire Rescue Service of the Czech Republic on demand (in case of need).

Because of the Sentinels data policy (which is the game changer) is rapidly growing the number of applications and use cases, mainly on agriculture and forestry, natural resources management, infrastructure monitoring, sector of energy and the others.

Copernicus Relays and Copernicus Academy contributes on awareness rising about Sentinel data and its applications. Hackathons organized mainly by ESA BIC generates a lot of interests among both students and companies.

Among the interesting achievements could be also counted 3 space Oscars for the Czech companies during last 2 years (2017, 2018).

Measures

(41) To maximise benefits of Copernicus: It is strongly recommended use the Copernicus data across the sectors (public, business, academia). Enabling this purpose the "National supportive tools" should be able to support the development of new high-added value services and applications. The Sentinel Collaborative Ground Segment, as the Sentinel data mirror site, dissemination platform and on the fly services providing platform should be maintained and further developed. Especially in the field of environment, transport, agriculture, urban development etc. the Copernicus data and services are the data and services tools for fulfilling of the targets of national policies. To maximise the benefits of Copernicus data and services is needed to maintain and further develop appropriate national awareness rising structure, initiatives like Copernicus Relays and Copernicus Academy, ensure the involvement on international competitions (e.g. Copernicus masters), organize national competition and hackathons; maintain ESA BICs´ incubation scheme, which facilitates transfer of the ideas into the practice and maintain the Copernicus National User Forum conference. As already described, in order to develop the capacities of the Czech Republic in Copernicus, the Czech Republic has to participate in the ESA programmes like Future EO, Copernicus Space Component -4 and InCubed.

<u>Galileo and EGNOS</u>

Analysis

Although the Czech Republic has been financially supporting the EGNSS programmes within its overall contribution into EU budget, the involvement of Czech industry in Galileo and EGNOS has been very low. Both programmes have a very long development history reaching back to the times before Czech Republic joined ESA, when the Czech industry did not possess neither the right business connections nor competences to compete with the countries from Western Europe. The situation is getting slowly better, as the Czech industry has been increasing their level of competence and reputation in the European space business, mainly through ESA programme. The direct industrial involvement into EGNSS is even more difficult than ESA programmes, because Galileo and EGNOS are implemented under EU rules and conditions, without the measure of guaranteed geographical return. Another obstacle for getting involved are frequent demanding requirements of possessing security clearances both for companies and their employees, to be able to bid for Galileo invitations to tender.

Measures

(42) To maximise benefits of Galileo and EGNOS: To increase the competitiveness of Czech industry, the Czech Republic should further support the industry in the frame of ESA programmes and look for new partnerships under the EU HSNAV programme within the Horizon 2020 and later on the Horizon Europe. Industrial partnerships with the European large system integrators and industrial companies one level below, should be encouraged, so that Czech companies get involved into the procurements second generation of Galileo including the so called Transitional Batch, which should build a technological bridge between first and second generation.

Govsatcom

Analysis

Govsatcom at a programme level offers several opportunities to Czech Republic. First of all, it can provide affordable secured communication services for authorised users like police forces, fire-fighters, Czech army or secured diplomatic channels for the president, prime minister and other security demanding purposes. Access to Govsatcom services should be free of charge for institutional and governmental users unless the European Commission decides on a pricing policy. Second aspect is the connection is the management of the security aspects of the EU Space Programme (e.g. security accreditation) by the new EU space agency EUSPA, which will grow from the current GSA in Prague. Since the security accreditation will be one of the key operational processes in the Govsatcom programme, the EUSPA in Prague will play a major role in the Govsatcom implementation and operation. Thirdly, the Czech industry can participate in preparatory projects in the frame of ESA Govsatcom Precursor programme, Govsatcom related activities under Horizon 2020 and Horizon Europe, or through the activities under preparation by European Commission or projects by EDA. Finally, although there seem to be ample of industrial opportunities under the Govsatcom umbrella, many of them are, however, directly linked to the needs of the concrete user groups in member states.

Measures

(43) To maximise benefits of Govsatcom: The Czech Republic should consider the use cases of Govsatcom services, which will become available after 2020. The Czech Republic should also continue in its efforts in looking for project opportunities in available programmatic tools of ESA, EDA or EU R&D programmes or through direct EU procurements, for development and further advancement of the Govsatcom system. To be able to focus on the potential benefits for the specific needs of the Czech Republic, a coordinated engagement of domestic user groups is needed.

SST Support Framework / SSA framework

Analysis

EU SST Support Framework (SST SF) is implemented by the SST Consortium, which consists of national designated entities of five EU Member States (France, Germany, Italy, Spain and United Kingdom), responsible for provision of the SST services (see Chapter 4.4.2.2.1, and EU Satellite Centre that operates Front desk portal. As of end of 2018, a new Consortium Agreement and Implementing Arrangement were negotiated with additional EU Member States willing to become full members of the SST Consortium (Poland, Portugal and Romania). Regarding the technical, logistic and security/governance requirements to join the initiative as a full member of the SST Consortium (at least two SST assets of different types under national control/ownership, establishment of national operation centre for SST etc.), another 8 EU Member States, incl. the Czech Republic, expressed its will to join the SST SF as an Aspiring Member States in order to cooperate with the SST Consortium in a different forms (subcontracts etc.). The whole process of initiating cooperation with Aspiring Member States was postponed until the creation of a new unified EU Space Programme (due to intention to transform SST SF into an EU SSA framework), composed of SST, SWE and NEO sub-element.

Forthcoming EU SSA Framework should provide additional financial support:

- To develop new national SST sensors, new active removal and passivation measures of space debris; additional space and ground SST infrastructures;
- For mapping and networking of existing European SWE and NEO capacities;

- To provide SWE services based on user needs and MS capacities with 24/7 coverage and to enhance SWE modelling techniques;
- To create a European catalogue of NEO, to develop a routine rapid response services able to characterise newly discovered NEOs;
- To promote and ensure enhanced international cooperation across all SSA sub-elements.

Measures

(44) To develop appropriate procedures and conditions for the participation of Czech entities in the EU SSA framework: The SST SF/forthcoming EU SSA framework represents an opportunity for Czech industry and academia with relevant expertise in various aspects of SSA. The Czech Republic should consider establishment of a national office to fulfil these tasks and contribute to the European Commission's efforts to consolidate SWE, NEO and SST capacities of its Member States and contribute to global SSA initiatives.

<u>Horizon Europe</u>

Analysis

The Czech Republic has been participating in previous Horizon 2020 Space and FP7 Space with comparable success in relation to other central and eastern EU countries. There are 2 main domains of our participation on Horizon 2020 Space – satellite navigation and Earth observation. But the Czech academia is highly interested also on scientific data processing and SSA related activities. Because of growing capacities on space sector in the Czech Republic it could be expected also increasing number of project submitted to Horizon Europe. There was also several projects related to space (mainly EO) submitted to non-space Horizon 2020 domain (Climate Action, Environment, Resource Efficiency and Raw Materials; Science Education etc.). That discovers, that the real Czech absorption capacities on space related activities are much higher. As an obstacle could be felt lower average success rate of the projects.

Measures

(45) To examine all possible ways how to increase the participation of Czech entities in Horizon Europe: National Point of Contact (NPC) and other communication and awareness rising platforms has to be exploited much more intensively in comparison to the period 2014-2019. The set-up of a link, for leverage, between ESA optional programmes and EU activities supported by Horizon Europe has to be implemented.

<u>Others</u>

Analysis

There are EU internationalisation programmes for SMEs, above all in Asia, which include courses on learning the business cultures, thematic events and B2Bs or exhibition participations. These activities also include good financial sponsorship from EU.

Measures

(46) To encourage Czech space industry to take advantage of the EU internationalisation programmes or other EU tools: Czech industry needs to make use all opportunities which EU designed to help in its internalisation.

6 EVALUATION

To be able to evaluate whether the objectives of the NSP will have been achieved and to which extend the NSP will have been implemented, it is necessary to define quantifiable evaluation criteria including Key Performance Indicators (KPI’s).

Assumptions for meeting KPI’s:

- The Czech Republic’s contribution to ESA optional programmes is at least three times as high as its contribution to ESA Mandatory Activities.
- The funding of the payload projects of space missions especially through PRODEX programme is stable and sustainably growing.
- The annual contribution to C3PFP is at least at the same level as was in 2017, 2018 and 2019.

Evaluation criteria and KPI’s are the following:

- Increased capacities and capabilities of Czech industry and academia and increased return-on-investment generated from contribution of the Czech Republic to ESA mandatory activities, ESA optional programmes and C3PFP:
    - At least 100 projects implemented via ESA mandatory activities, ESA optional programmes and C3PFP.
    - At least 1 ambitious project as described in NSP implemented in the Czech Republic.
    - Balanced participation of academia and industry in space projects with at least 90 % of the budget of the ESA mandatory activities, ESA optional programmes and C3PFP spent in Czech industry.
    - Overall return-on-investment (economic impact factor) on such contributions to ESA including ESA Mandatory Activities of a factor of 5.
    - At least 2 new Czech PIs or Co-PI in a space-based scientific instrument assuming the funding of the payload projects of space missions is stable and sustainably growing.
    - A minimum of 2 new Czech-owned-IPR sustainable space product being supplied or about to be supplied.
    - At least 2 new products that are supplied to European primes and 3 new products supplying European sub-primes in sustainable fashion.
    - ESA BIC platform will expand at least to another one city in the Czech Republic and extend its incubation capacities to at least 15 start-ups per year.
    - At least 10 space industry days with other states or prime contractors organized by state entities or industry to increase national and international cooperation and networking.
    - At least 10 graduates finished their training through formalized training support scheme.
- Increased public awareness about space activities
    - At least 30 events (hackathons, space nights, conferences etc.) organized to inform general public or experts about space activities in the Czech Republic and their benefits, science and business opportunities etc. and/or to attract attention of various age categories.
    - At least 20 competitions including annual challenges of such competitions implemented.
    - At least 12 000 teachers supported in STEM education according to ESERO model and at least 400 000 students reached by ESERO activities.
- Increased international cooperation in space activities
    - At least 2 agreements and/or memorandum of understanding type of document concluded/signed to support international cooperation is space activities.
- Increased state use of space or satellite based data
    - At least 5 projects using space or satellite based data implemented or to be implemented by state entities as users.

7 ANNEXES

A. MARKETS AND TRENDS

1) EARTH OBSERVATION

Earth Observation (EO) is currently going through a paradigm shift. It is becoming to be a regular source of data.

Among main drivers could be counted mainly rapid development on ICT, technology development and commercialization, New Space – massive private investments on new EO constellations and last, but not least decreasing launch costs for new missions. Sentinels fleet becomes operational since 2014 and provides terabytes of data on basis of full, free and open Copernicus data policy per day. Due to this policy the costs of the data aren´t projected into the costs of the services. This stimulates new EO spaceborne data based applications and services development and stimulates the EO downstream sector in general.

New paradigms and new visions of the value chain:[7]

- Cheaper systems and ground segments;
- Multi sensors ground processing systems;
- Lower cost / reliability and higher replacement rate;
- B2C / Mass market / Vertical integration;
- Data analytics;
- Free of charge imagery to enter new markets;
- New solutions for Capex / Opex optimization;
- Scalability, i.e. the capacity to start business before the full deployment of the system.

Market overview

Commercial space products and services increased for 8.3 % to gain a 55 % share of global space activities. Commercial Infrastructure and Support Industries grew by 7.5 %, maintaining 25 % global space activity share.[8] It is expected[9] that around 340 EO satellites will be privately financed, either fully of partly, for launch over the years 2017-2026. This includes 10 constellations counting 320 satellites (excl. nano- and micro- sats). This means 8 billion USD investments over the decade, 12% of commercial space.

The downstream market shows constant growth at an expected CAGR of 7 % up to 2022.

In 2017, the European EO economy was valued at between €2.7 billion and €3.1 billion. The EO upstream segment was valued at €1.9 billion, which represents about two thirds of the revenues of the European EO economy. The revenues of the downstream market amounted to between €0.75 billion and €1.2 billion.[10]

From 2008 up to 2020, the total investments in the Copernicus programme are forecasted to reach €8.2 billion EUR. Over the same period, this investment will generate economic benefits between €16.2 billion and €21.3 billion (excluding non-monetary benefits). This economic value is generated through the added value created in the upstream space industry, the sales of Copernicus-based applications by downstream service. 93 % of economic benefits are generated by end-users.[11]

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[7] Denis, Gil, & company; Towards disruptions in Earth observation? New Earth Observation systems and markets evolution: Possible scenarios and impacts; Acta Astronautica 137 (2017) 415–433.

[8] The Space report; Space foundation; 2018.

[9] Euroconsult: Satellites to be build @ launched by 2026 – world market survey; 2017.

[10] PwC; Copernicus Market Report; 2019.

[11] PwC; Copernicus Market Report; 2019.

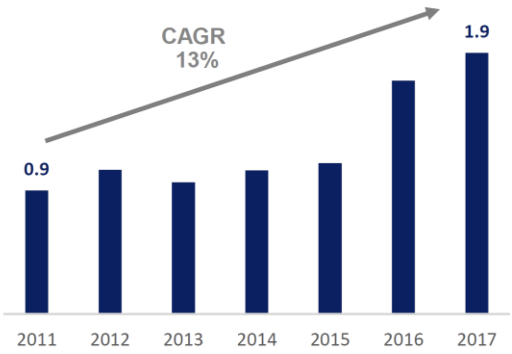

Figure A: Evolution of European EO upstream sales [billion €]. Source PwC; Copernicus Market Report; 2019.

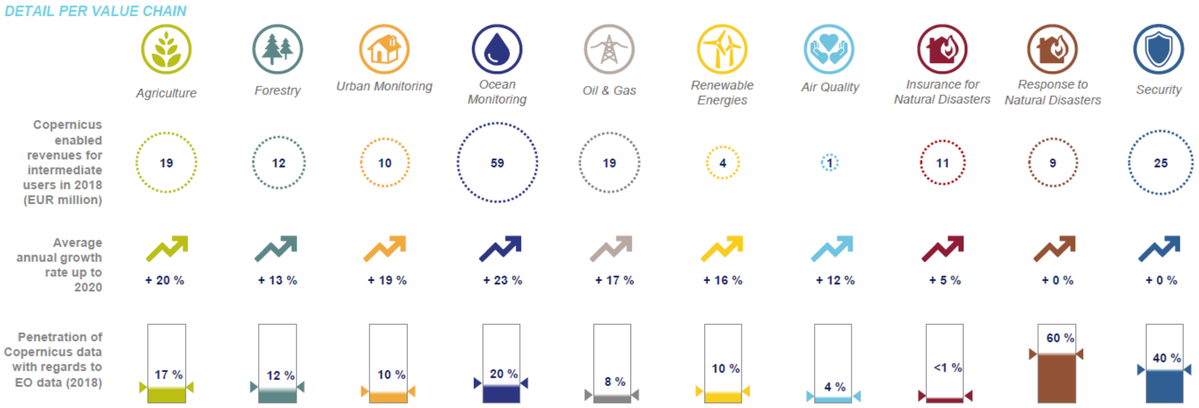

Figure B: Overview of the growth of Copernicus benefits on the most valuable sectors. Source PwC; Copernicus Market Report; 2019.

Economic benefits for the end-users are expected for €2.7 billion in 2018 with 14% growth up to €3.5 billion in 2020. The most promising sector growth for 2020 (in comparison to 2018) are Forestry (+46 %), Agriculture (+31 %), Renewable energy (+25 %), Oil and Gas (+17 %) and Urban monitoring (+17 %).[12]

Current trend is going towards very high resolution (VHR) data combined with higher temporal resolution. There is a continuous and worldwide growth of the VHR imagery market.

- The value chain is shifting from the raw data to services and applications;
- Value for money: there is a strong pressure to reduce infrastructure and operational costs;
- Hybrid procurement schemes, combining proprietary missions and data buy framework contracts, partly triggered by the budgetary constraints of public customers;
- New space and disruptive initiatives are developed not only by start-ups but also by large players with a huge investment capacity. Both aim at transforming space (EO) as a commodity;
- New players are targeting the export market.[13]

[12] PwC; Copernicus Market Report; 2019.

[13] Denis, Gil, & company; Towards disruptions in Earth observation? New Earth Observation systems and markets evolution: Possible scenarios and impacts; Acta Astronautica 137 (2017) 415–433.

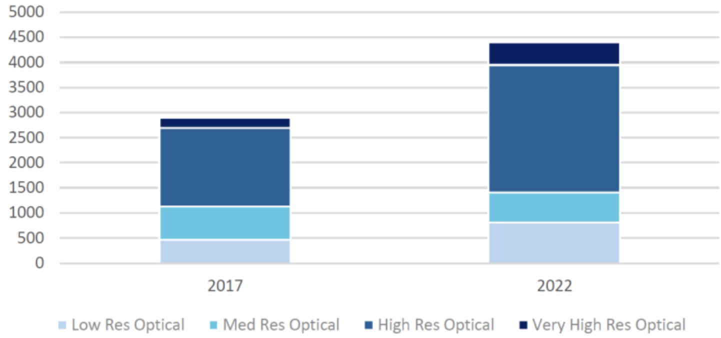

Figure C: EO Optical Market by Resolution 2017-2022 [million €]. Source PwC; Copernicus Market Report; 2019.

Because of the growing market is growing the number of new companies entering into the EO downstream domain.

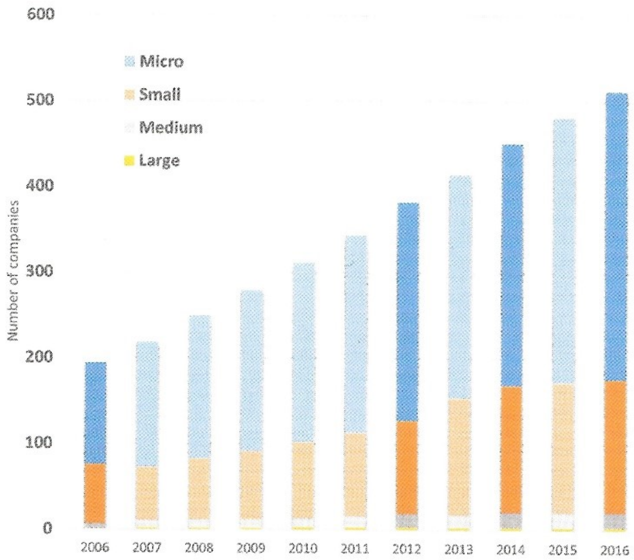

Figure D: Growth in the number of companies. It could be seen that highest growth is on micro-sized enterprises. Source EARSC; A Survey into the State & Health of the European EO Services Industry; 2017.

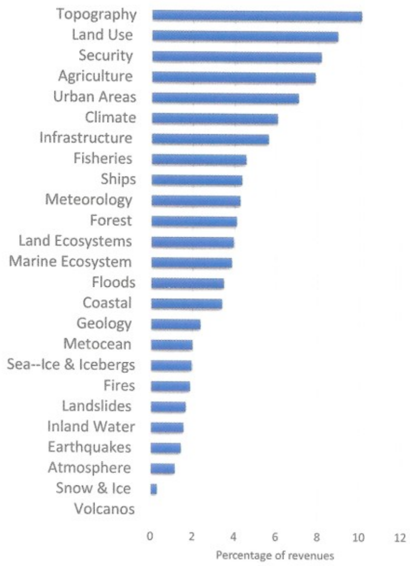

Figure E: Thematic segmentation based on revenues. Source EARSC; A Survey into the State & Health of the European EO Services Industry; 2017.

Technology drivers and trends

Trends on technology development

There are a several technology trends strongly influencing the Earth observation domain. Among the main one especially the following:[14]

- **Miniaturisation** of platforms and payloads; new types of lightweight sensors and related apparatuses (both optical and SAR), advanced IT processors, advanced optical and SAR solutions, incl. using of new materials. Trends are going towards keeping of the big satellites performance on mini / micro satellites; much faster data downlink via both optical telecommunication and bandwidth radio spectre using communication.
- **Reprogrammable HW**, which could be customised in accordance with current user needs; uploadable SW.
- **Dual – use** missions provides data for both military and civil applications. The mission also could have two kinds of payload, the first one focused on civil apps and the second one, e.g. with much higher spatial resolution for IMINT use only.
- **Multi-services missions**, which integrates e.g. EO and SatCom. Because of difficulties especially in orbital mechanics and partly also on size of the satellites it is expected as minor trend line. This technology could be of interest in the case of SatCom constellations at LEO with a stabile orbits favourable to EO and also in the case of large satellites for GTO.
- **Small satellites constellations and networks; multilayer-EO** using combination of satellite, high altitude platforms and drone data. Developing and operating constellations of small, low-cost EO satellites delivering data geared towards specific end users. New small satellites are used for expansion of observational capacity and capability of currently operated bigger missions.
- **Life cycle** of both, technologies and services development phase is going to be much faster today. Especially for the market pioneering companies is extremely important would be able provide data and services as soon as possible, within one or two years at maximum.
- A new value chain for "**low-cost satellite EO**" is being developed including satellite and sensor manufacturers, integration and tests providers, communication systems and operations services providers. Downstream services are been developed, aiming at irrigating economic sectors with appropriated analytics for agriculture, resources monitoring, transports, maritime surveillance and many other sectors. If stakeholders agree on the fact that few projects will be operational and that the space EO sector landscape will evolve, no one will make a prognostic in a domain where agility is the rule of the game, and where some players have already change their business model twice.[15]
- **On-board autonomy** is one of the key areas of potential innovation. An increased degree of on-board autonomy helps in implementing more effective mission operations. In particular, functionalities like event detection, autonomous planning and goal management, if implemented on-board, introduce several benefits to the way operations are managed.[16]
- **Artificial intelligence** data processing will rapidly increase the effectivity of the mission and effectivity of its operation. Because of that, the mission will be able to decide what to observe and how to meet customer needs.

New data sources

User requirements on data quality, spatial, temporal, spectral and radiometric resolution stimulates demand for new data sources and new missions. In line with technology trends and decreasing launch costs, lot of new companies are starting to develop their own EO satellites or constellations. Some of the missions are developed directly for very specific tasks / applications they will serve for.

The EU in close cooperation with ESA planes to enlarge the family of Sentinels, which will cover spectral bands uncovered by current generation of Sentinels. Because of the super-friendly full, free and open

[14] ESA sources.

[15] Denis, Gil, & company; Towards disruptions in Earth observation? New Earth Observation systems and markets evolution: Possible scenarios and impacts; Acta Astronautica 137 (2017) 415–433.

[16] Fefuglio Lorenzo; Deep learning for enhanced on-board autonomy: EO applications; 2018, Phi-week.

data policy it could expected as stimulation for downstream segment. It is expected development of new Sentinel capacities at P-band and L-band SAR, thermal infrared and also at hyperspectral imaging. The goal for future Copernicus dedicated observation capacity (Sentinels), based on user requirements and discussion are mainly the following:[17]

- Assure continuity and increase the robustness of the existing CSC in the future;
- Increase the quality and quantity of the existing measurements / observations;
- Consolidate European EO system leadership and reference role;
- Expand observation types according to policies and user needs;
- Employ latest technologies for maximum efficiency.

Number of the new Sentinels depends on budget available on the EU and ESA site.

Because of demand for services a technology and market trends described above are the New Space players coming with multi-constellations for EO; namely Planet, ICE and others. These constellations would be able to provide much higher temporal resolution, what is one of the key parameters for customers. The trend is to develop small, spectrally rich satellites, which will have fast revisit.

Highly competitive technology for constellations will be the High altitude platforms / pseudo-satellites (HAPs). It would be non-orbiting platforms in very high atmosphere, which will enable get temporarily and spatially high resolution data. One of many advantages of HAPS will be the real on demand imaging, which is in case of satellites limited by the orbital mechanics. Coordinated systems of HAPS could cover huge areas and could be considered also as competitor for space data on the level of smaller regions. HAPS in such coordinated systems play a key role in bridging the gaps between data access, resolution and time resolution we find limiting on current EO systems.[18]

Multi-platform and multi-technology observations in combination with data fusion with geospatial data, digital maps and attribute data will have a huge potential for innovative services and new applications. It will very likely address new markets for which has current space data to low performance.

Both of the trends, EO constellations and HAPS will cause the demand on midstream services (satellite operations, downlink stations, data dissemination and others).

Given the fact of growing demand on calibration and validation (cal/val) of the results computed on the basis of remote sensing data, the networks providing cal/val data are highly demanded. Cal/val data will become extremely important input for AI remote sensing data analysis. IoT and SatCom technologies development will enable get the cal/val data on demand. That will have a highly positive impact on quality of the EO analysis results. That is why it is expected, that this kind of networks will be built in near future (incl. the virtual ones, builds on basis of existing sensors).

Data distribution

Data distribution and dissemination could be seen from two points of view. The first is strictly technical: capacity of distribution channels, size of data storages and overall ICT performance used for data processing. All of these parameters are the key for data / product distribution centres. Because of the rapidly growing number of data and information users, is the ability to ensure data distribution one of the bottle neck of the overall value chain. It is expected that with growing number of commercial data providers will also increase demand on downlink and data distribution segment. This could address development of new midstream part of the EO market.

The most extensive EO data distribution network in Europe has the Copernicus programme. Sentinel data are distributed via 4 hubs: Open Access Hub (general public), International Data Hub, Collaborative Ground Segment Hub and Copernicus Services Hub, all of them provided by ESA. On the European Commission side has been launched the Data and Information Access Service (DIAS) initiative, as the successor of former Integrated Ground Segment vision. DIAS services, incl. data distribution, are currently (2019) on the initial phase of its operation. In spite of that, with regards on the ESA initiative of Sentinel Collaborative Ground Segments, most of the ESA Member States develops

[17] ESA resources

[18] Sills Lian Ronald, The Role of HAPs IN Future Multilayer EO Systems; 2018, Phi-Week.

their own data dissemination structure, as a support for national users. The reason is lack of capacity on current data dissemination networks, both Open Access Hub and DIAS.

It could be expected, that DIAS will be for the future focused more on end-user service provision, than on data dissemination.

Based on the statistics, the private sector starting to be the key data user segment. As for the number of users, the “general public” prevails, but looking on the numbers of regular basis data downloaders, they are companies, public sector and academia, who are the most important users (that means not general public).

It could be expected rapidly growing need for midstream services, like data downlink stations /systems, data distribution a product dissemination platforms. Because of growing number of EO satellites and constellations, demand for data downlink and processing on the product shall grow. High capacities available on data distribution and storages is the backbone for data dissemination centres.

No less important parameter is the data and information policy applied of the respective observation systems. Copernicus full, open a free data policy boost the EO sector in Europe as never be seen before. The price of the data is one of the biggest component of the price of the service (information, product based on EO data). Being data free of charge, the prices of the service (information, product) is going to be lower and that´s why more competitive. Copernicus data policy is the game changer on the overall sector with huge influence on high resolution data and service market.

Data processing and service development

The worldwide EO commercial sector is generating new economic activities by applying of the very new data processing approach. Main role on data processing of the future will play in particular: Artificial Intelligence and Cloud Computing, which transforms EO space data and contextual data to value-added information, reorganizing traditional EO markets through digital platforms that adopt advanced IT technologies. Especial the AI data processing has the potential be a game changer. Virtual reality could be counted as promising method as well.

The trend is going **from EO** applications to **gEO** applications. New EO data based products naturally starts to be combined with other spatial data products, like digital maps sensor network measurements and the others. Drivers are data integration, data fusion, interoperability and synergies with other technologies (blockchain, IoT, etc.). In order to meet end-user requirements the service providers starts develop customised products for respective users. Trends going towards domain indexes (insurance, agriculture, climate, etc.), change detection indexes, alerts and forecast systems and in the most advanced form to customised indexes. Because of huge amount of data and quickness of data processing, which the users are asking for the automation of data processing is emphasised.

Because of the need for fast data processing of huge amount of data, the processing platforms based on cloud and distributed computing will play an increasingly important role. In order to maximise the return of investment, the service providers would like to maximise the number of users per for each pixel of satellite image.

As mentioned above, because of growing importance of cal/val information, it could be expected that in-situ networks (based on IoT) will became stabile part of midstream segment.

External drivers

- **ICT development**: Rapid increase of CPU and GPU performance in past years has been the key enabling factor for processing of high amount of data at timeframes needed for near real time applications. The capability process all of satellite data generated by operational missions (and time series of these data) is crucial assumption for sustainable services. That is why most of the services are going to be processed by cloud computing platforms, which provides the results via thin clients or via web browsers.
- **High speed data and communication networks** enables transport of huge amount of data. This is a general assumption for data and products dissemination. This is the driver for the amount of data, which could be transferred to the end-user.
- **Blockchain** will address the use of Distributed Ledger Technologies (DLT). It is perspective new technology for validation of data integrity, value chain participants’ identity and reputation, data

freshness, processing reliability and cyber security, key factor for stimulation of downstream industry growth and overall service quality and reliability. Geodata will be typically processed in a decentralized manner involving modules and processing capacities of diverse participants. Data will be managed and matched with other data, analysed, and packaged into value-added geodata and ready-to-use geoservices. Capabilities of the smart contracts will become more advanced over time. The blockchain tokens can fundamentally simplify all processes in the value-add chain. By providing low cost, assured trust in the integrity of data and transactions, blockchain can make it dramatically easier to trust, own, share and sell services from this exploding new sensing and communication infrastructure. Providers of geoservices can offer their assets based on tokens to the participants in the community. Blockchain could also rapidly increase security of distribution chain and trust that the data / results are not modified during the distribution to end-user.[19]

- **Development on IoT** will rapidly change collection of cal/val data, which are absolutely crucial for high reliability of automatically generated services.
- **Private investments on launchers** develops the launch market. Because of new players the capacity for launches has increased and the prices are remaining stabile or slightly going down, because of cheaper launchers. With this regards the launches ceases to be such high barrier.
- **New global and social challenges** stimulates development of new services. It is related on the ever-increasing need continuously and sustainably monitor the changes and measure it. And very often it is Earth observation, which offers the data for such kind of monitoring.

General trends:

- **Ecosystem approach** on the overall value chain (from production of data sources – satellites / HAPs, data distribution and processing to a customised application development).
- **Amateurisation of EO**: The users would like to stay just "users", not EO data processing experts. That´s why the results (of the analysis) has to be presented as easy to understand.
- **Continuously growth of data:** how the time is going, there is more and more data to be stored and processed.
- **Growing importance of midstream**, operation of public and private satellites and constellations.
- **New Space:** private satellites and constellations provides data for apps developers. New venture capital sources are needed for support of the whole value chain.

Czech Republic

The Czech service providers and users should be ready to use the system and available EO data. To secure the competitiveness of Czech EO service providers and the competency of the users at all levels, the national space programme should support implementation and coordination of all EO activities at national level.

Copernicus has opened a wide field of opportunities for national institutions, business and academia as well. All the users (governmental, industry and academia) has a new data source for their activities: decision making, business and scientific research. It could be seen growing number of users in comparison to last period (2014-2019). There is also higher amount of geoinformation oriented companies, which are able to process EO data into products. In spite of continuous awareness rising there is a limitation on the user site. Potential users are still not fully aware, what kind of benefits could EO bring to them and that has also impact on limited motivation to use new EO based services in practice. EO is still felt as a new, but very promising technology among the users.

ESA BIC, established by MT and operated by CzechInvest, has very positive role on stimulation of new start-ups development. Start-ups feels ESA BIC as the initiative, which helps them growth and enter with their product into the market. This is very positive, because very good idea holders, afraid of the entrepreneurship are starting turn their ideas into products for the market. Hackathons, user

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[19] Stocker Carsten; Space Based „Digital TwinL on Earth Brings Affordable EO Insights to the Other Seven Billion of Us; 2018, Phi-Week; Drimaco, Daniela; Evolving EO Data Trading by means of the Blockchain technology, 2018, Phi-week; Moradi, Yashar; How Blockchain-based GeoSmart Contracts Fuel the IoT, 2018, Phi-Week.

workshops and conferences are also great stimulators for new business development and usage of EO data and applications.

Catching the trends the Czech companies start to develop their services on user platform basis using data fusion, incl. full implementation of the results into the systems of the users. Some of the companies starts to develop AI based solutions.

To summarize the Czech downstream market overview, it is on the phase of expansion. The market is still not fully penetrated and there is a huge potential for development and implementation of new EO based services and application into practice. The most promising areas are agriculture, forestry, infrastructure monitoring, urban development, energy and environment and resources monitoring. Because of global data coverage of EO satellites, there is very good potential to penetrate also European or global market. Some of the companies start develop their products as global (in spite of specific conditions at respective places).

The Collaborative Ground Segment (CollGS) initiative of ESA, established by MD and operated by CESNET in the Czech Republic plays significant role on data access and distribution on the Czech Republic. Data distribution and quick data access is one of the bottlenecks for users. CollGS, as a mirror site, provides bandwidth data access to Sentinel data covering the Czech Republic and near surroundings. To stimulate Sentinel data use, the calculation and application platform should be developed.

The activities on the forthcoming period should be focused on the penetration of the EO based services / apps into daily lives and into respective agendas of governmental institutions as regular source of data.

Apart from the development and utilization of services, the EO sector involves a whole set of hardware development related to remote sensing sensors, optical systems, advanced data analysis techniques and data processing and distribution infrastructures. In these areas, the Czech subjects made an effort and strengthen their capacities in comparison to last period. Czech industry is able to deliver also sophisticated parts of the payload of satellite components and it is able to enter into European delivery chains. There is also some potential on HAPS technologies development and operation of the overall HAPS systems.

2) NAVIGATION

Current situation

Global navigation satellite systems (GNSS), which allow end users and small electronic receivers to determine their location to precision within a few meters, around the globe, have become an integral of our everyday life. According to the GNSS market report[20] elaborated by GSA in Prague, there were approx. 5.8 billion GNSS devices in use on the planet in 2017, out of which 5.4 billion (93 %) were smartphones. Almost 8 billion GNSS devices is forecasted to be used by 2020. The smartphones are the most popular platform supporting mobile Location-Based Services. In terms of the number of units in use, Road follows LBS with only 380 million devices in use in 2017. The installed base of devices used for road applications is expected to grow with a CAGR of 11.4 % due to EU eCall legislation. Although the number of GNSS devices in use in the professional market segments is lower, billions of people globally benefit from them daily, e.g. by using efficiently coordinated transport networks or GNSS-synchronised telecommunications networks. With a maturing regulatory environment, the installed base of drones is expected to reach to over 70 % of the installed base by professional market segments in 2025.

[20] GSA 2017: GNSS Market Report, issue 5.

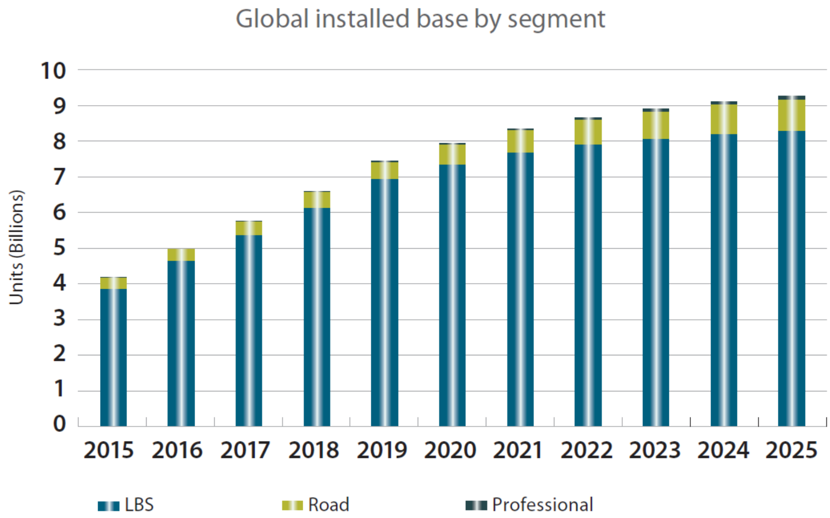

Figure F: Global installed base of GNSS receivers by market segments. Source: GSA

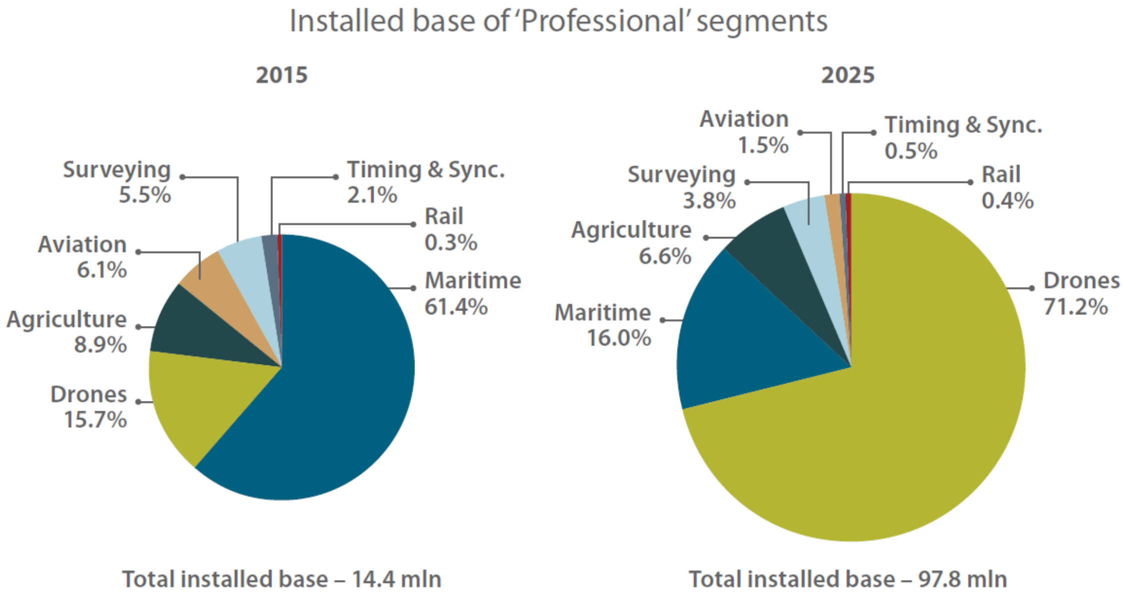

Figure G: Installed base of professional GNSS receivers by market segments. Source: GSA

The global GNSS downstream market basically consists of the sales of GNSS receivers and revenues from provision of augmentation services. The market is forecasted to grow by about 5 % annually, but slightly decelerating to towards 2025 due to its growing maturity leading to increasing competition and pressure on prices. The downstream market enables the development of added-value services and applications, which utilize the GNSS-based positioning. These are expected to grow between 2015 and 2020 at 20 % annually, gradually slowing to about 10 % through 2025. In 2015, the added-value market size for the first time exceeded the combined size of GNSS devices and augmentation services. The advent of 5G, Automated Driving, Smart Cities and the IoT is set to spawn a rapid proliferation and diversification of these added-value services. Their annual revenues will hit 195 billion Euro in 2025, which is more than 2.5 times higher than the expected GNSS device and service revenues that same year.

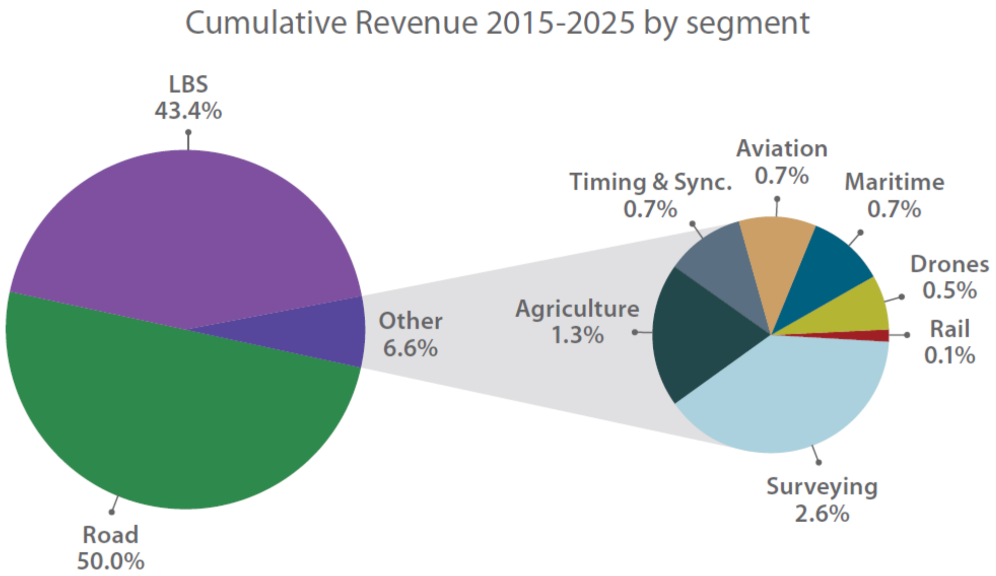

Figure H: Estimated cumulative revenue between 2015-2025 by market segments. Source: GSA

The United States leads the global GNSS market with 29 %, while Europe (EU28 + Norway and Switzerland) with 25 % has claimed the second place in terms of 2015 revenues. China's GNSS industry is growing rapidly, accounting for 11 % of global revenues in 2015. The European Galileo system should reach its full operational capability in 2020 and already provides global positioning services for Galileo enabled receivers. Even though the Galileo system is not finished yet, due to high quality of its signals, it is being already recognised by chipset manufacturers as a reference constellation, alongside the GPS. Unlike the other global GNSS systems – GPS, GLONASS and BeiDou, the Galileo stays fully under EU civilian control. EGNOS, the European Satellite Based Augmentation System (SBAS) fully operational since 2009, increases the accuracy of GPS positioning and provides information on its reliability (integrity), making it suitable for safety-critical applications. Although it was designed primarily for aviation, it has been widely adopted in segments such as agriculture and road. An enhanced third version of EGNOS is under development, main new features will be multi-constellation concept, wider coverage area and use of dual-frequency. Other complementary augmentation systems like Atlas, SmartNet, StarFire, TopNet, VRS Now or the Czech CZEPOS, provide observation and correction data via GSM or SatCom means, proved to be viable at the professional market segments.

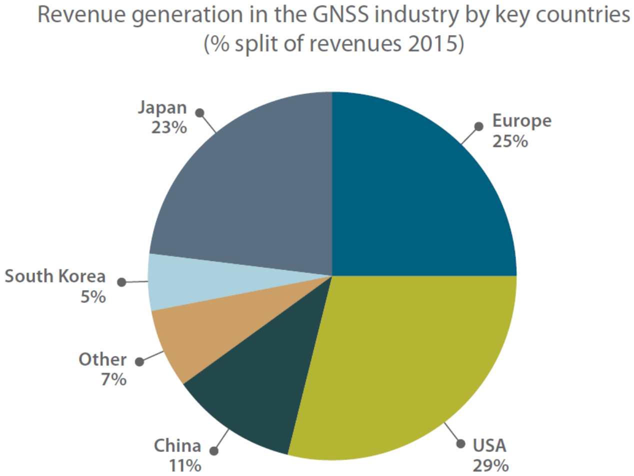

Figure I: Revenue generation in the GNSS industry by countries (% split of revenues in 2015). Source: GSA

As the core GNSS downstream industry, the market of component manufacturers is becoming increasingly consolidated. Underpinned by a number of recent mergers and acquisitions, the industry's two leading companies – Qualcomm and Broadcom (now Broadcom Limited owned by Avago) –

together account for over 40 % of revenues. System integrators primarily comprise car manufacturers and smartphone vendors, for which GNSS represents only a small part of their products. GNSS currently offers an increasingly large potential for context aware applications. Their revenue will reach over 30 billion Euro by 2019, a market size three times larger than in 2015.

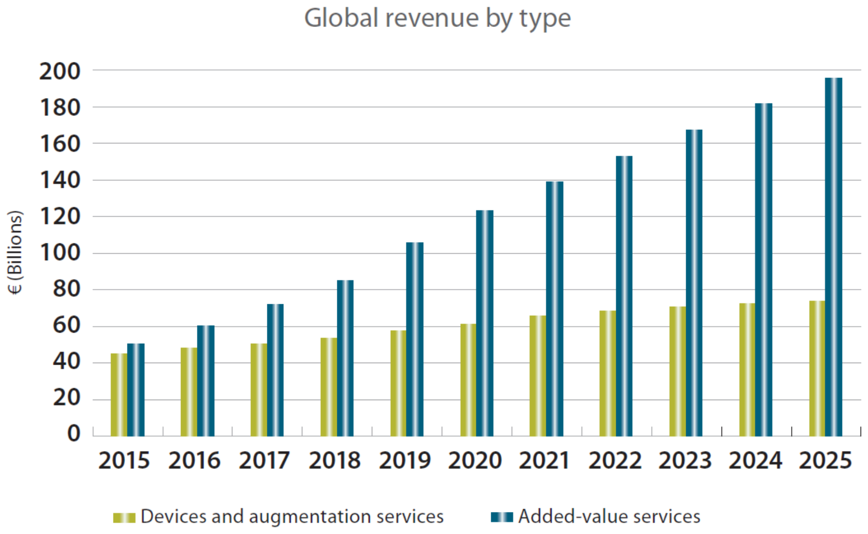

Figure J: Global revenues by type of market source. Source: GSA

To complete the picture, the upstream sector of GNSS, in contrary to SatCom domain, cannot be for the time being considered a market as such. The sector is completely under control of relevant governments and it doesn´t have contours of institutional market (like in Earth Observation domain) as well, as the competition is restricted to local entities.

Trends

The PNT market is steadily pushing the needs for global positioning capability with horizontal precision down to a sub-meter level. In this context the Galileo High Accuracy Service will play a key role as a high precision positioning market accelerator. GNSS has already become an essential element of major contemporary technology developments. **Internet of Things (IoT)** allows vehicles, buildings and other objects to be interconnected and remotely controlled. IoT is relying on a wide range of different sensors including GNSS. In the ever-growing need for processing **Big Data** volumes, GNSS brings location and timing into the picture. **mHealth** is a sub-segment of eHealth and covers medical and public health services supported by GNSS enabled mobile devices. Unlike virtual reality, which creates a totally artificial environment, **Augmented Reality (AR)** uses the existing environment and overlays new information on top. GNSS allows the creation of a direct link between the surrounding reality and digital objects. **Smart Cities** feature an integrated system for collecting, measuring and broadcasting data about the cities towards citizens, municipalities and city planners. GNSS is one of the key technologies used within infrastructure design and mobility. **Multimodal logistics** service providers draw on GNSS for its efficiency, security and safety features. GNSS contributes to the monitoring of cargo along the entire supply chain and enables asset management. The GNSS market report recognises eight distinct market segments, which consist of many individual and diverse applications. All of them keep steadily evolving and innovating.

- **Location-Based Services (LBS)** include smartphones, tablets, digital cameras, fitness wearable devices and mobile data revenues. Apart of classical navigation and digital mapping & GIS, the trending applications include geo marketing and advertising, safety and emergency, enterprise applications, sports, games and augmented reality, mHealth and of course, social networking. Over 90 % of context-aware smartphone apps now rely on GNSS, incl. Galileo (more than 900 mil. smartphones in 2019). A growing number of premium smartphones is going beyond dual-constellation by integrating multi-constellation GNSS chipsets, thus further increasing accuracy, availability and time to fix. Location-based services in mHealth are driving the diversification and sophistication of wearables and smartphone apps for healthcare. Availability of GNSS raw measurements on smartphones opens new possibilities for app developers.

- **Road** segment contains Personal Navigation Devices (PNDs), In-Vehicle Systems (IVS) and on-board units (OBUs) for navigation, fleet management and satellite road traffic monitoring. The safety-critical applications utilize the GNSS positioning for Advanced Driver Assistance Systems (ADAS) and other cooperative and Intelligent Transport Systems (ITS) including data revenues for traffic information services. Liability-critical applications include Road User Charging (RUC), Pay-Per-Use-Insurance black boxes (PPUI). The regulated applications in the EU include smart tachograph and the well-known eCall, which is mandatory for all new cars on the EU market from April 1st 2018. GNSS, together with other technologies, is a key answer to Autonomous Vehicles' need of accurate positioning combined with reliability of localisation. Whilst OEMs and technology companies are leading the development of Autonomous Vehicle, governments across the world encourage these efforts and allowing testing on public roads. Business models continue evolving, with OEMs pushing towards the ownership of GNSS data and aftermarket companies increasingly specialising in data collection and elaboration.
- **Aviation** segment features regulated applications using certified equipment to achieve safe and efficient operations in for commercial, regional, general & business aviation. It includes Performance Based Navigation (PBN), Emergency Locator Transmitters (ELTs) and Automatic Dependent Surveillance – Broadcast (ADS-B). In the unregulated market, many recreational pilots using Visual Flight Rules (VFR) make use of GNSS applications like moving maps, infringement alarms and Personal Locator Beacons (PLBs). The market with drones is booming and these vehicles including UAV/RPAS incorporate GNSS not only for their location and navigation, but also to avoid flying into restricted airspace. Regulations for operating drones is being currently prepared in the EU. The aviation market continues to grow worldwide with reliance on GNSS increasing. Rotorcraft operations are currently rapidly expanding their use of SBAS. Regulators support expansion of PBN (particularly in Europe by 2020), resulting in significantly expanded role of GNSS in aviation – over 150 new runway ends enabled since the previous market report – and in the future using Multi-Constellation / Multi-Frequency (MC/MF). ELT ruling increases expected sales and further enhanced by Autonomous Distress Tracking (ADT) capabilities.
- **Rail** GNSS based solutions can offer enhanced safety for lower cost, namely in railway signalling. Depending on the region, e.g. in India, China and the Middle East, GNSS begins to be implemented for safety relevant applications at different levels of maturity. The typical case is in safety-critical devices supporting signalling high and low density lines, e.g. in European Train Control System – ETCS. In the non-safety critical area, GNSS devices support applications such as asset management Driver Advisory System (DAS) for optimised operation of train traffic or passenger information systems, which show the real-time location of a train along its route.
- **Maritime** users utilize GNSS as the primary means of obtaining Position, Navigation and Timing (PNT) information at sea. Traffic management and surveillance are supported by GNSS-based systems including Automatic Identification System (AIS) and Long-Range Identification and Tracking (LRIT) both in sea and inland waters. Search and Rescue operations provide aid to people in distress or danger i.e. by Emergency Position Indicating Radio Beacons (EPIRBs) and Personal Locator Beacons (PLBs) transmit, once activated, the necessary information for rescue to authorities via SatCom. SAR beacon manufacturers are preparing for multi-constellation GNSS, opening the path for Galileo penetration in all type of SAR beacons. Other applications include fishing vessels control, port operations, and marine engineering. GNSS is a key enabler for both traditional and innovative maritime applications and operations such as the use of drones and the development of smart ships.
- **Agriculture** GNSS applications are used across all phases of the agricultural life cycle and represent a key enabler for the integrated farm management comprehensive concept. GNSS enabled applications for precision agriculture include farm machinery guidance, automatic steering, asset management, variable rate technology, yield and soil condition monitoring,

livestock tracking and forest management. Apart of the traditional applications mentioned above, agriculture is also likely to be one of the largest users of the drone technology. Also the Internet of Things (IoT) has been the source of new and more productive ways to farm, owing to the use of easy-to-install and affordable sensors. The US is leading and worldwide the segment is growing at a CAGR of 20 %.

- **Surveying** has been supported by GNSS devices traditionally for land surveying, with high precision positioning enabled by multi-constellation receivers and complementary augmentation techniques and data corrections (EGNOS and other SBAS, D-GNSS, PPP, RTK). The applications include cadastral mapping, construction and mine surveying, infrastructure monitoring and marine surveying. Falling prices of GNSS devices and data crowd sourcing drive the democratization of mapping and help to advance the concept of smart cities. Incumbent manufacturers are focusing on customer services and assistance to counterbalance Asian manufactures' competitive pricing strategies. The integration of GNSS with complementary technologies in land surveying and construction is a major push towards interoperability. GNSS remains the backbone technology in increasingly sophisticated applications, e.g. 3D mapping.
- **Timing & Synchronisation** is the newest and least known market segment, although GNSS timing is at the core of many critical infrastructures, including telecoms, energy and finance. SatCom operators require accurate and consistent time and frequency at distant points of their networks to face increasingly demanding broadband requirements. GNSS is at the heart of Digital Cellular Networks (DCN), Public Switched Telephone Networks (PSTN), Professional Mobile Radio (PMR), SatCom and Small cells. Expansion of telecom networks like Small Cells, 4G and the onset of 5G makes GNSS more and more essential, driving future shipments. Energy operators require an accurate time source to monitor and protect the network energy flow by Phasor Measurement Units (PMUs) in the frame of systems like WAMS, WAPS, WACS and WAMPAC. Financial institutions are legally committed to trace operations with a consistent and accurate time scale. Hence, GNSS time stamps are being used by banks and stock exchanges. The T&S community is facing many challenges linked to an increased need for resilience, reliability and security, supported by an evolution of the regulation.

Czech Republic

The Czech Republic already benefits from the applications offered by satellite navigation and actively supports the development of new technologies that exploit the potential of satellite navigation. Czech companies regularly take part in the Galileo Masters as well. We can see several Czech entities involved in different market sectors like manufacturing GNSS receivers, development of GNSS algorithms, precise orbit determination and development of GNSS based integrated applications. However, due to highly dynamic nature of the sector, support from the public domain is needed. Apart from the European Horizon 2020 themes focused on GNSS and GSA's Fundamental elements programme, the Czech Republic supports the R&D research and technologies and applications development through ESA programmes, namely the Navigation Innovation and Support Programme (NAVISP), Integrated Application Promotion Programme (IAP) and possibly also Technology Research Programme (TRP) and General Support Technology Programme (GSTP). Strategically, more attention is still needed in research and development of countermeasures to GNSS interference, namely jamming and spoofing. This issue is especially relevant in the context of operation of critical and important infrastructures in the sectors of transportation, telecommunication, power engineering, banking and ICT, which depend either on the PNT information or on the GNSS time.

3) TELECOMMUNICATIONS

Current situation

The satellite telecommunication (SatCom) market is probably the most mature out of all space markets. Governmental, institutional and commercial SatCom segments are all well developed and they form a significant part of the whole satellite industry. According to the Satellite Industry

Association's State of the Satellite Industry Report (edition 2018),[21] the global satellite industry revenues reached in 2017 almost 269 billion USD (it doubled since 2007), and form about 79 % of the global space economy. The bulk is composed mainly of revenues coming from satellite services (128.7 billion USD, 48 %) and sales of satellite ground equipment (119.8 billion USD, 45 %), while the revenues created by the heavy and traditional satellite manufacturing (15.5 billion USD) and launch industry (4.6 billion USD) form mere 7 % altogether and they have been stagnating or slowly sinking. The global satellite industry revenues, however, have been growing steadily by 2-3 % annually since 2015.

The SatCom domain participates significantly in all satellite industry segments, such as provision of satellite services (98 %), ground equipment (18 %) and satellite manufacturing and launch industry (34 %). The largest (97 billion USD) source of revenues comes from provision of satellite TV, which is the source of 75 % of revenues from all satellite services and makes for 36 % of all revenues by the whole satellite industry family. The satellite TV, including radio and satellite internet broadband revenues have increased from circa 20 billion USD in year 2000 to almost 100 billion USD in 2018. What has been also changing during these years is the pattern of user demand. It has been shifting from constant data demand (satellite TV) to very variable demand of online streaming services.

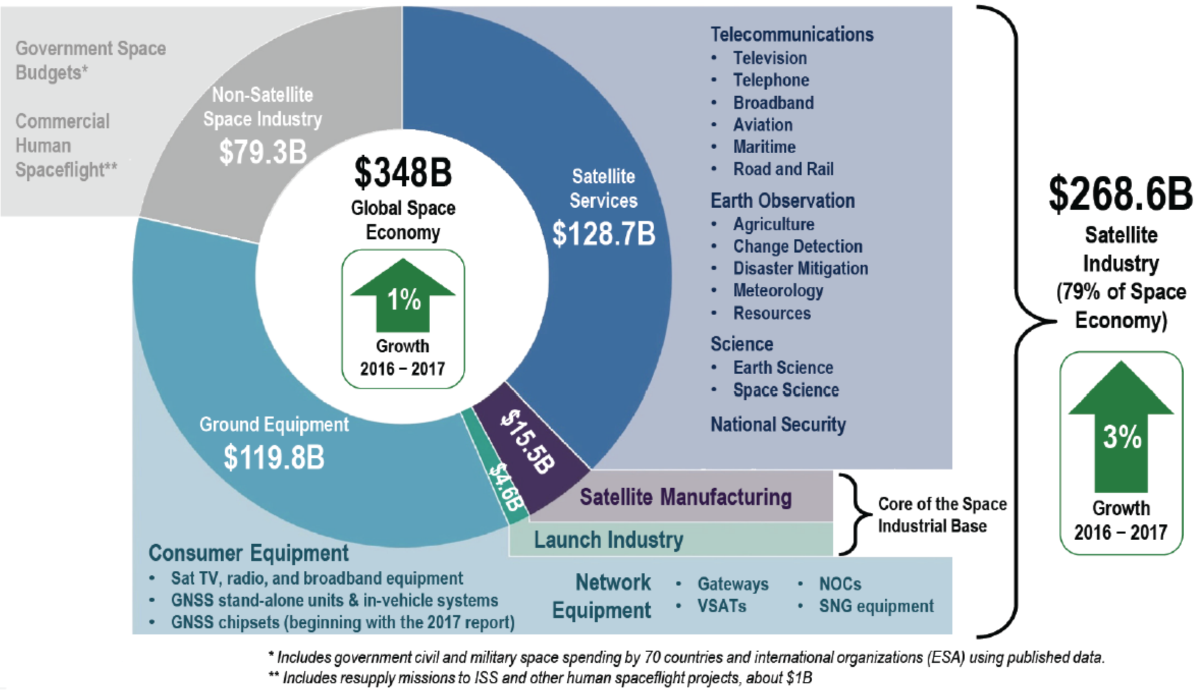

Figure K: Space industry revenue. Source: ESA presentation of SIA State of the Satellite Industry Report 2018.

To put the numbers into context, the whole satellite industry revenue is only about 17 % higher than the revenue of Apple (229.2 billion USD) in the same year and the satellite services revenue compare to about 72 % of the revenue of Amazon (177.9 billion USD). Analogically, the satellite TV revenue in 2017 roughly compares to the revenue of Google (109.7 billion USD) in the same year, while the revenue of satellite manufacturers is only a bit more than the revenue of Netflix (11.7 billion USD).

[21] SIA State of the Satellite Industry Report 2018

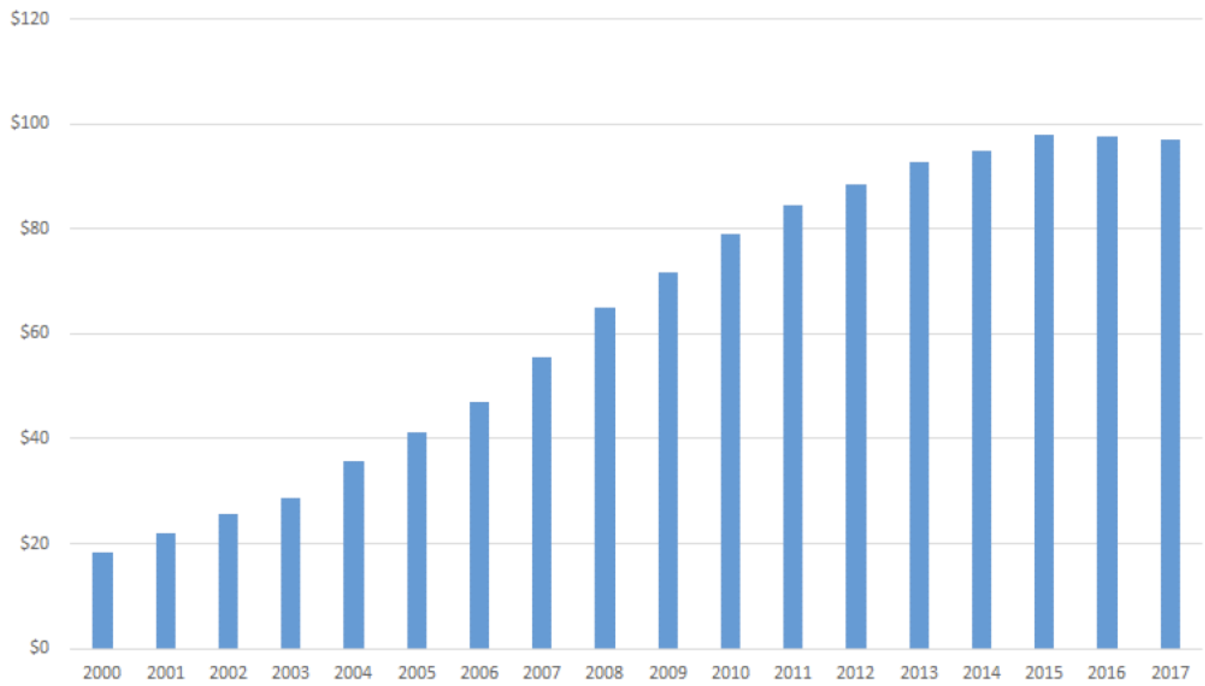

Figure L: Satellite TV revenues. Source: ESA presentation of SIA State of the Satellite Industry Report 2018.

From the spacecraft point of view, there have been more than 1730 operational satellites in orbit in 2017, out of which 43 % were devoted to SatCom (31 % commercial, 11 % governmental, 1 % non-profit). In total circa 350 satellites have been launched into space in 2017, out of which 21 % were communication satellites. From all satellites launched into space in 2017, circa 61 % came from the USA, 30 % from Europe and the rest from China (4 %), Japan (3 %), Russia (1 %) and other countries (0,2 %). The US satellite manufacturers have also been more successful in acquiring large GEO satellite orders, than the European manufacturers.

The satellite operator revenue has been steadily sinking since 2014 and it was 38 % below the level called „business as usual", which is a theoretical level, that could be reached, if the operators' business grew constantly at the same rate, as it did from 2004 till 2011 and there were 20-25 orders of geostationary (GEO) satellites per year. Since 2011, however, the demand for new GEO satellites has fallen to about 10 spacecraft per year and the prices per Mbit of transmitted data are falling down. In this overall pessimistic picture, it is only Chinese operators, who are doing quite well (AsiaSat, APT Satellite) and whose revenues are still growing. Most of the other operators like Avanti, Eutelsat, SES, Intelsat or Telesat have been experiencing decreased revenue compared to previous years.

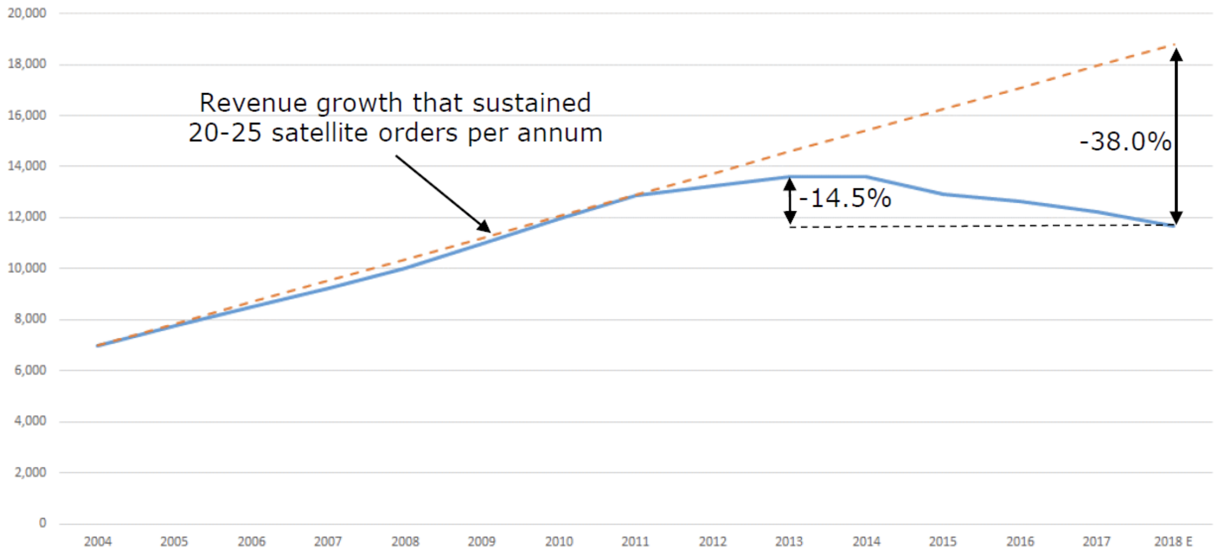

Figure M: Satellite operator revenue vs business as usual. Source: ESA presentation of SIA State of the Satellite Industry Report 2018.

As ESA reports in its Long-Term Plan 2019-2028[22] the SatCom sector has been facing unprecedented dynamic competition fuelled by the opportunities that the digital transformation of many economic sectors offer to SatCom. The non-GEO megaconstellation SatCom sector is developing both as a source of growth and disruption. New actors with strong background funding are emerging. The paradigmatic change in the production of satellites and satellite equipment brought by the megaconstellation model has a high potential impact on the traditional SatCom manufacturing industry. The GEO satellite market is now at a crossroad with two main directions: larger satellites integrating maximum capacity (VHTS – Very High Throughput Satellites, UHTS – Ultra High Throughput Satellites) and flexible smaller satellites taking advantage of the low-cost high-volume production introduced with the megaconstellations.

Profound transformation of business activities is under way with the 5G worldwide deployment after 2020 and the introduction of first mobile 5G communications standard. To mitigate the risk that satellites will not fit into the new 5G paradigm, number of worldwide and European initiatives are ongoing with the strategic aim of smooth integration of SatCom systems into future 5G terrestrial networks. These partially publicly funded initiatives are focusing on development of combined technology standards (cellular, Wi-Fi, SatCom) and 5G SatCom demonstration projects, pioneering the use of SatCom 5G at occasions like Olympic games and other large scale public events.

As regards to new SatCom developments in Europe, ESA's ARTES programme has delivered number of technologies, products and systems, funded usually under a public private partnership scheme. The European Data Relay System (EDRS) is already operational and provides gigabit-speed data relay services to four Sentinel satellites of the EU Copernicus programme. A new SmallGEO platform has been developed and launched into orbit, as the Europe's response to the strong market demand for smaller, flexible and modular SatCom platforms for geostationary orbit.

The development of the next generation 3-6 ton geostationary telecommunication platform (NEOSAT) is almost completed with product line qualification reviews planned for 2020. The global coverage upgrade of the EDRS system (GlobeNet) is on the way, developed in cooperation with Airbus Defence & Space, with the aim to cover the Asia-Pacific site of the globe in 2023. Another significant European SatCom initiative is the IRIS programme, where ESA, in cooperation with Inmarsat, will contribute to increased safety of European air traffic management (ATM) system. The aim is to promote and gradually introduce SatCom ATM services with airlines after 2020. ESA has recently also initiated a large number of specific cooperation schemes with SatCom operators like ViaSat, OneWeb, SES, Hispasat and others, supporting development and pilot demonstrations of new technologies and services, including global internet coverage and development of megaconstellations.

[22] ESA Long-Term Plan 2019-2028.

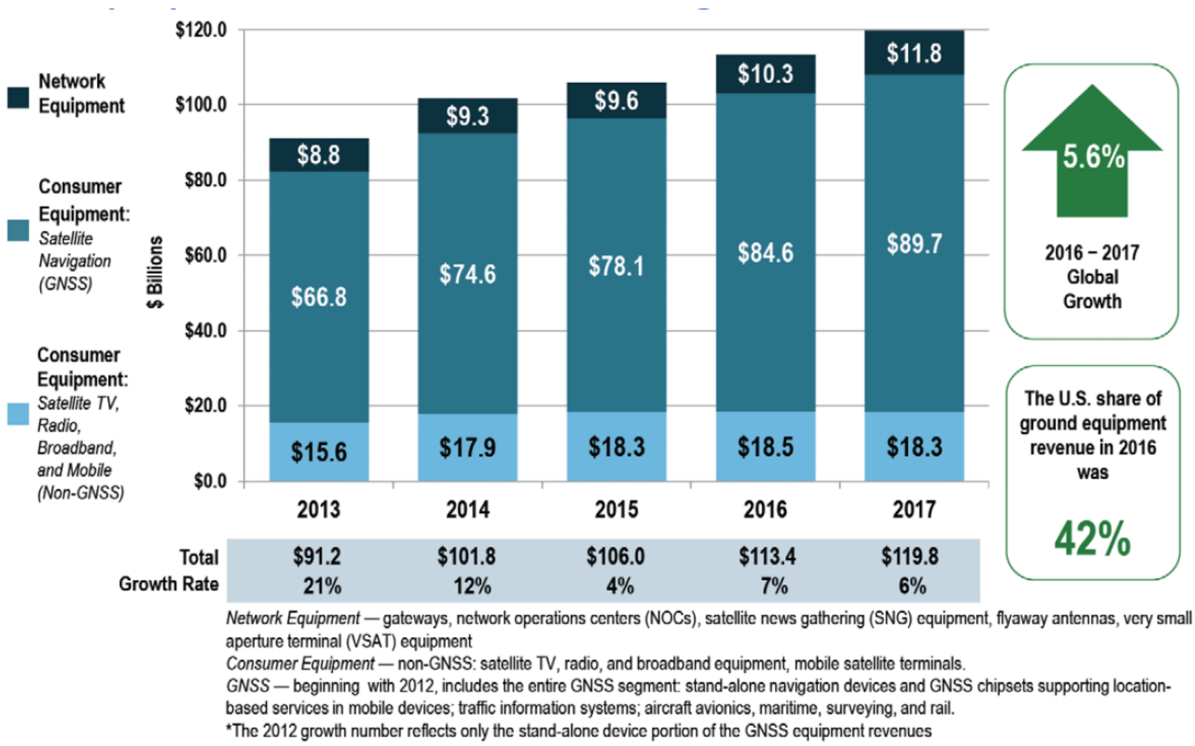

Figure N: Ground equipment revenues. Source: ESA presentation of SIA State of the Satellite Industry Report 2018.

Trends

The world SatCom market is experiencing a profound digital transformation, which will drive future investments. In Europe, the focus should be on fostering public-private partnerships investing into high-risk new technology evolutions to shape future markets and strengthen the position of the European industry on the global market. ESA will play a key role in this by supporting the development of innovative and high-risk elements of future SatCom technologies, systems and integrated applications in the frame of ARTES programme.

The future trend might look in two distinct ways, depending on the level of maturity and reliability reached by new disruptive technologies, namely very small satellites and unmanned aerial vehicles. Without that disruption, the SatCom markets might grow at over 70 % CAGR, with an extreme dispersion of growth rates between rising and declining technologies. It will be a very uncertain market. If the disruptive scenario occurs, the forecasted CAGR might reach under 110 % until 2025 and the new technologies might even kill some of the legacy technologies. Traditional fixed SatCom services will be losing market share to mobile services. The key element of future SatCom will be its smooth integration to terrestrial fixed and mobile communication networks, with no adverse effect on the end user experience. End user SatCom terminals will continue to get more compact, with advances in C-Band, Ka Band, and Ku Band technologies.

Euroconsult in 2016 estimated that not more than 14 large GEO SatCom satellites be launched per year after 2021, although governmental SatCom including military might compensate the low volume of commercial orders. It is the demand of online high and ultra-high definition Live video streaming services for mobile end users with smartphones and tablets, which will shape the SatCom market in the coming years. Because the terrestrial telecommunication infrastructures do not cover the whole globe, usually due to constraints of the natural environment or lack of national investments, many regions of the planet are not yet online. These areas bare potential customers and dormant commercial opportunities for online businesses.

Therefore, many experts, commercial enterprises and private investors decided to develop the next generation of communication satellite systems, usually designed as regional / global constellations or even megaconstellations. These will be composed of tens, hundreds or even thousands of individual small satellites positioned at low or medium Earth orbit. The goal of these systems is that the space

segment would work very economically with the terrestrial communications backbone, even in sparsely populated regions, where the local installations are limited. There is a new market emerging of small and very small satellites like microsats and nanosats/cubesats. Their launch can be very cheap, because many unites fit on single launcher and they are well suited to form large constellations. They bare low costs of development and manufacturing, especially in large series production, but they are limited in individual throughput and power capacity. Cubesats will likely support only the low-end market, e.g. Internet of Things (IoT), Machine-to-Machine communication (M2M), Store & Forward Messaging or Satellite Automatic Identification System (Sat-AIS). Significant upstream and downstream revenues require constellations with larger satellites, like smallsats up to 500 kg (OneWeb, StarLink by SpaceX), medium sized satellites of 500-1 000 kg and constellations with large satellites above 1 000 kg (O3b, TelesatLEO).
The envisaged constellations, which seem more credible, are amongst large number of smaller and cheaper satellites (e.g. OneWeb). The largest constellations (e.g. from SpaceX) are less credible due to impossibility of launching the constellation mass in required time horizon. Euroconsult estimates that 6 200 satellites will be launched between 2018 and 2026. None of the manufacturers of these constellations, however, has yet started his production, and the new-space satellite operators have yet to earn their first revenue. They need to find the right market niche with customers (the very need to emerge), then learn how to operate, grow and survive the competition for services provided by others.
To be able to produce hundreds of cheap and yet reliable satellites in relatively short time, completely new serial production chains have to be developed by satellite manufacturers. This so-called new-space approach has been slowly emerging, but needs to be tested in real life conditions and by the market. We can therefore expect that future SatCom technologies will be much smaller and cheaper. Some of the SatCom like services may not even be delivered by satellites, but by high altitude platforms (HAPs) in the atmosphere. It is estimated, that SatCom applications form about 40 % of global HAPs market, which will reach circa 500 million USD in 2024.

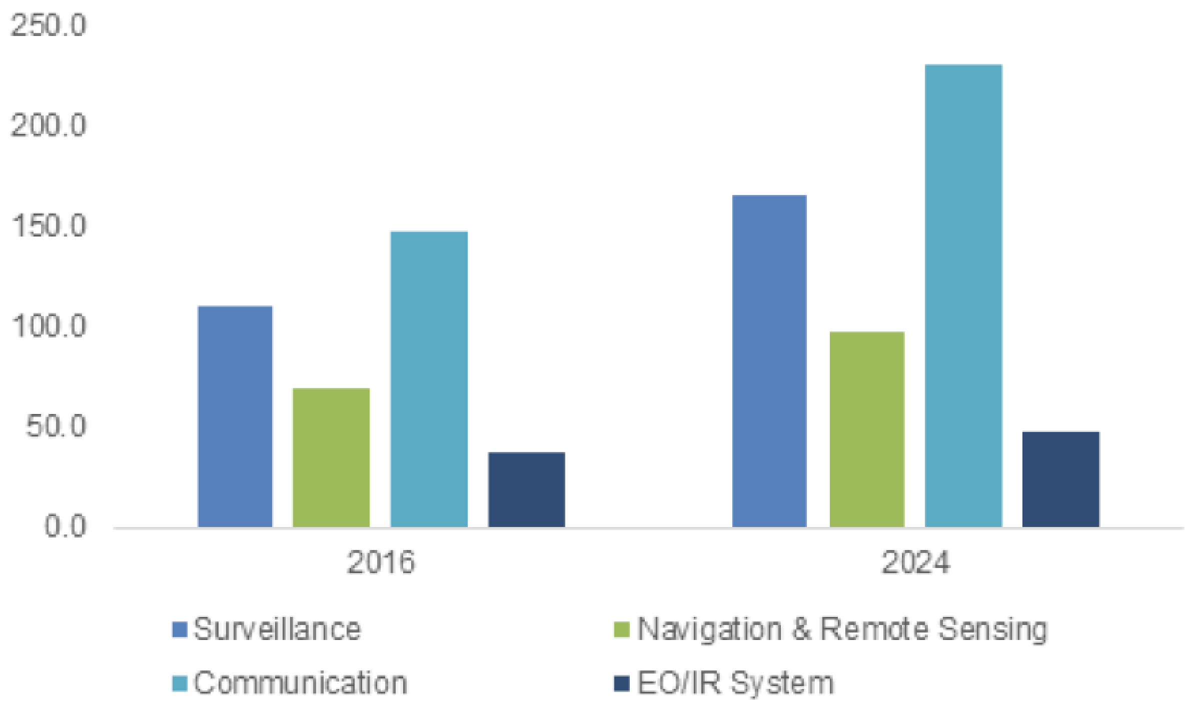

Figure O: US HAP market size by application (million USD). Source: ESA

At the opposite end of the scale of the spacecraft size, the large GEOs might get even larger, mainly to deliver high throughput consumer broadband (High Throughput Satellites, e.g. ESA's NEOSAT platform series). GEOs for other applications will be getting smaller and cheaper with shorter life but with higher capacity than previously (e.g. ESA's Small GEO or Quantum).

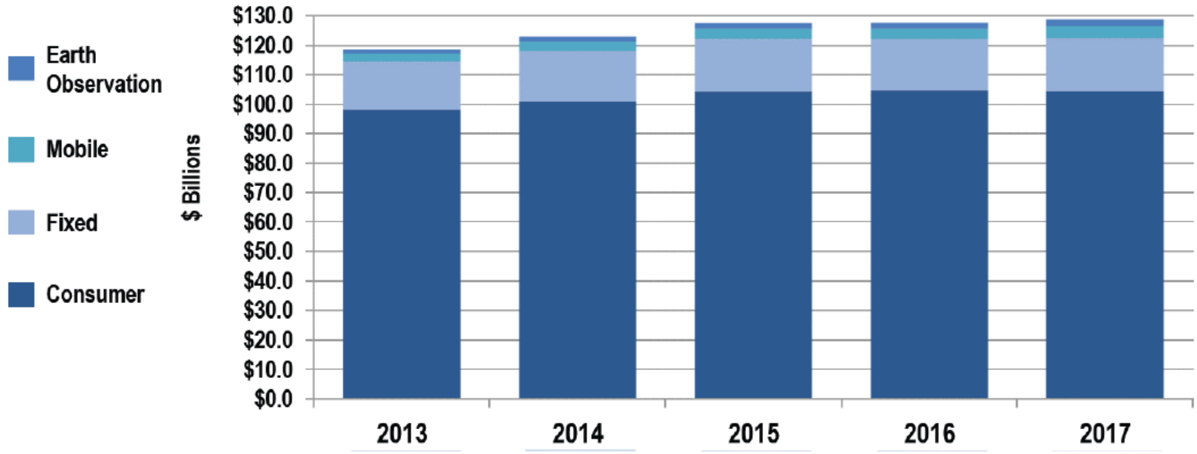

Figure P: Satellite services revenue. Source: ESA presentation of SIA State of the Satellite Industry Report 2018.

Since the current consumers already demand uninterrupted access to unlimited data bandwidth, any time and everywhere, the traditional radio SatCom technology has reached its limits due to limited data rates and ionospheric attenuation. As reported in the Global Commercial and Military Satellite Communications Market and Technology Forecast to 2025[23], development of optical SatCom technologies and systems will foster the current GEO and future LEO SatCom constellations, since lasers will increase data rates circa 100x over radio. An example of such a system is the European Data Relay Systems (EDRS) and perhaps the future HydRON system, which is currently at the stage of an innovative project proposal in ESA's ARTES programme.

Apart from the above mentioned optical communication technologies, we can expect advances in mm wavelength communications (Q/V, W band devices), progress in scalable and efficient digital processing, developments of smart multi-beam antennas, large reflectors and flat self-scanning user terminals. Finally yet importantly, the digital transformation of the whole industry value chain will take place, including standards, techniques and processes, by which the communication satellites are developed and operated, with increased level of automation and involvement of robotics, artificial intelligence, machine learning, blockchain technologies and with introduction of non-space (e.g. automotive) materials, components and processes for use in space.

Most of the future SatCom systems will put an increased focus on safety and security aspects. From autonomous shipping to air traffic management and governmental communications, space based SatCom services will support new cyber/security future needs, e.g. in conjunction with blockchain and quantum encryption technologies. In Europe, the public sector involvement will be of paramount importance to set up GOVSATCOM, a new secured governmental SatCom system for authorised users in the EU. Regarding the security related SatCom programmes currently under development, the EDRS Globenet should reached the operational phase after 2020, as well as the IRIS programme, which will introduce SatCom for increased safety of air traffic management over Europe. In the more far future, an autonomous European SatCom system for quantum key distribution might be defined.

In the frame of ESA's ARTES programme, we will observe programmatic actions with following aims:

- To increase investments and enable competitive introduction of European innovative products and services in the world market and to address the fast-growing number of market opportunities and use cases;
- To enable a prominent role of satellite systems in 5G and a competitive positioning of the European players through new developments, pilot demonstrations with terrestrial players, opening 5G vertical markets for satellite, fostering new 5G applications enabled by satellite;
- To support new commercial downstream businesses from start-ups to SMEs or larger existing service providers; develop new innovative integrated applications using SatCom systems in

[23] Global Commercial and Military Satellite Communications Market and Technology Forecast to 2025

conjunction with Earth observation and satellite navigation; and seek interest of banks, funds and private investors;

- To foster the utilisation of new safety and security related satellites communications and to support competitiveness of the European industry on the corresponding world market, which has been often regulated by public entities or industries with special interests.

Czech Republic

In the Czech Republic, a few downstream service providers have been representing satellite networks operated e.g. by Eutelsat, SES Astra, Inmarsat, Iridium, Globalstar and Intelsat. Regarding popularity among customers, most of the SatCom services fall into the satellite TV category, although even this service is becoming less popular over time. The number of subscribers of satellite digital TV and radio broadcasting services sank from 1.72 million in 2012 to 1.15 million in 2017, because most of the services can now be accessed online. There has been a significant increase in the market size of high-speed internet broadband, namely in mobile LTE and wireless, but also in VDSL, cable and optical technologies, where the increase is smaller, but steady. However, the number of customers using SatCom access to internet is only in the order of hundreds of user terminals in the whole country and the same applies to SatCom voice services. The main reason is that the LTE coverage in Czech Republic is very good, offering reasonable speeds and affordable prices, in contrast to costly satellite phones with their expensive voice and data tariffs. Overall, the SatCom services are not very popular in Czech Republic, except for the consumer satellite TV. Satellite voice and data services are sometimes used by special user groups including public institutions, usually as back-up to more traditional communication means. A European GOVSATCOM initiative might facilitate further uptake of SatCom technologies in Czech Republic, as the services should become easily available and affordable for authorised governmental users.

Secondly, there is an emerging Czech footprint on the downstream market in the domain of SatCom user terminals and cockpit solutions for civil and military aviation. SatCom terminals are going to be embedded both in big passenger aircrafts and smaller unmanned aerial vehicles (UAVs also known as RPAS) including drones. The aim is to establish fast communication links between ground control centres and the aircrafts for transferring data, voice and high-resolution video, to facilitate new generation of Air Traffic Management services, provide new passenger experience and advanced surveillance capabilities for UAVs. In the upstream market, several companies are already integrated into technology supply chains, providing components and subsystems for communication satellites. The crucial support for all SatCom developments comes from the Ministry of Transport's budget through the ESA's ARTES programme, which helps to mitigate the risks and bridge the gap from R&D phase to product industrialization and qualification, before reaching the market through commercial contracts with large SatCom systems integrators. The aim here is to support the promising developments of companies, which could be successful on the market, help them advance and mature their products, widen their commercial product portfolio and introduce them to new potential customers.

4) LAUNCHERS

Current Situation

The launcher sector is changing dramatically in the past years. While there was on average 70-80 launches in the previous decade, year 2018 totalled 114 launches of which 112 were successful. Such launch rate was last seen three decades ago.

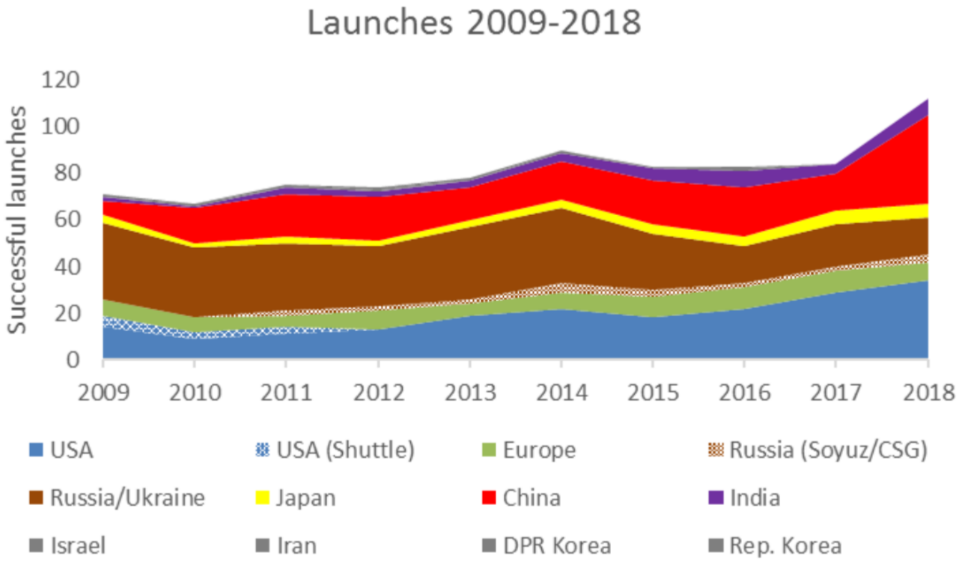

Figure Q: Launch activity worldwide – last 10 years

Europe maintains stable number of 11 launches per year while in 2018 US made significant increase in launch activity with 34 launches driven by SpaceX (21 launches) and even more so China with 39 launches becoming for the first time the global leader. At the same time, we see decrease in Russian launch activities stabilizing just below 20 launcher p.a.

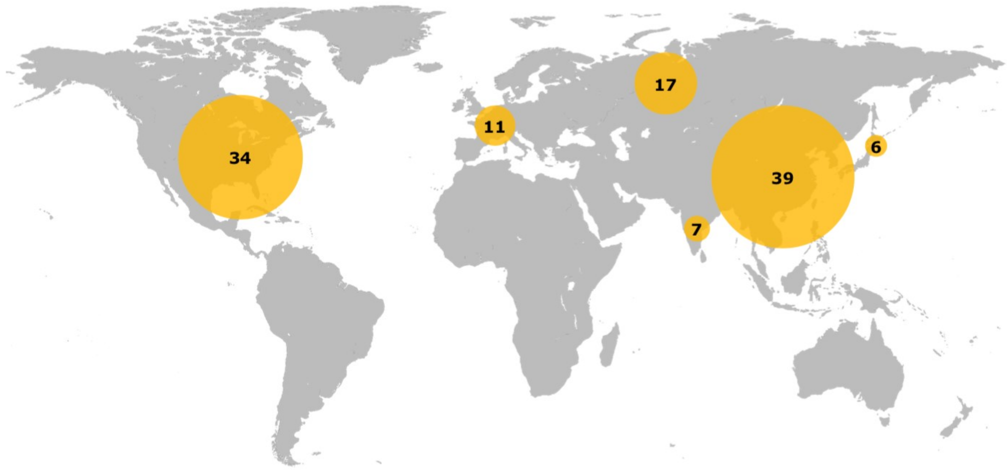

Figure R: Launches in 2018: 114

In 2018 Arianespace performed 11 launches: 6 Ariane 5 (8 commercial geostationary, 4 Galileo, BepiColombo), 3 Soyuz (4 constellation, meteorological, EO), 2 Vega (2 EO). Eurockot in 2018 performed one launch of EO satellite.

While European launcher industry represents less than 10 % of launches, it still maintains position of global player in commercial launches being able to acquire around half of the accessible market. Accessible market is an important term, since most of the launch service contracts are not accessible to European companies Arianespace and Eurockot due to national interests (mostly security and military) of states procuring the services. Those are then logically restricted to service provides from the respective countries – this is in particular case of US, Russia, China, Japan and India.

For states with geopolitical ambitions it is essential to have guaranteed access to space to be able to deliver in orbit any satellite needed to fulfil their national objectives. Of course, this is often driven by security requirements. Commercialization considerations are secondary except for Europe where commercial exploitation of European launchers has helped to minimize the cost of maintaining the launch system in operational condition.

European launcher programmes encompass two complementary market segments. Operational launcher systems are the segment in which the space industry produces and integrates the Ariane and Vega launch systems for Arianespace that subsequently sells the launch service worldwide. The level of business in this segment is driven mostly by Arianespace demand for launch system, itself being strongly linked to the global demand for launch services and by the competitiveness of Arianespace. The second segment is the export of launcher parts (e.g. fairings, nozzles) that are integrated to non-European launchers (e.g. Atlas in the USA, H2 in Japan) but this only makes 5 % of the launcher sales.

Market for launch system development activities includes development programmes that are funded almost exclusively through ESA, they aim at preparing the future (e.g. FLPP programme) or at consolidating and improving existing technology (e.g. ARTA, VERTA, LEAP programmes). The level of business associated to this market is driven by policy decisions. In CM14 decided to embark on the development of a new launcher system Ariane 6 as well as improved Vega launcher Vega C. The impact of the Ariane 6 development programme on industry revenues is quite visible.

ESA spending in launcher sector oscillates around a billion per year[24] including development, maintenance in operational condition of all European launch systems and European spaceport. The European launcher sector offers another billion-class business coming from commercial sales of launchers (including Soyuz commercialized by Arianespace) and parts.

Trends

While the number of launches peaked in 2018 the prospects for next years are unclear. There is a visible decline in demand for GTO launches due to unclear future of SatCom market which at one hand faces the problem of customers preferring the video on demand being served over data networks rather than the traditional direct-to-home TV. On the other hand, ground based solutions such as fiber is becoming more and more available to consumers even in remote areas. The operators are not sure whether to commit to procurement of new satellites with 15+ years life or rather wait how the market develops taking advantage of the fact, that their current satellite fleets is operational and will remain so next couple of years before the replenishment need will become imminent. This is clearly seen from drop of the contracts signed in 2018 from the long-time average of 20 just a few years ago.

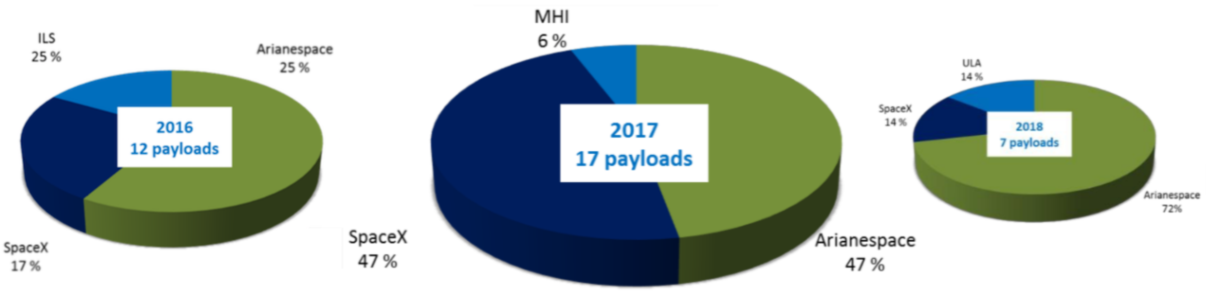

Figure S: Decline in GTO commercial launch services contracts signed

One of the possible futures is the mega constellations which however still have to prove business case. Not only little has been launched so far, but also the vast number of satellites (hundreds, thousands) is not compatible with current launching capacity. The viability of mega constellations is yet to be seen and orders of launch services are linked to beginning of mass production of satellites and number of related issues – funding, interference risk to GEO satellites, price of satellite receivers, space debris, regulatory framework adaptation (FCC/ITU).

Figures T and U illustrate the changing environment on the ration of institutional and commercial demand. While the number of European launches is stable, the context moves. While Russian competition is declining, Space X is attracting more and more commercial customers using aggressive pricing policies for commercial customers and benefiting from institutional contracts.

[24] ESA 2013: Cost plans of on-going Space Transportation Programmes in preparation of draft budgets for 2019 ESA/PB-LAU(2018)13.

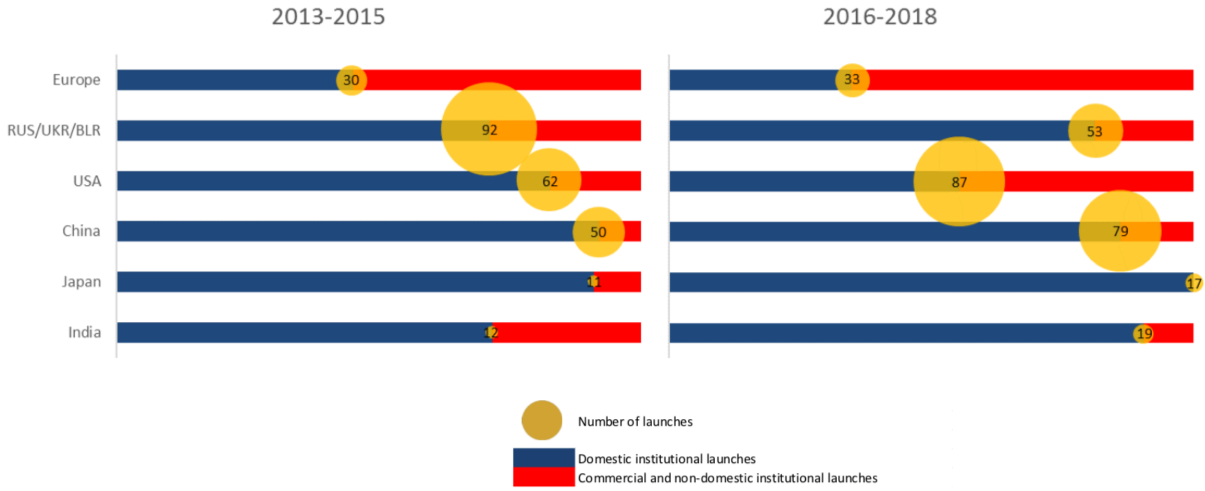

Figure T: Weight of institutional demand worldwide – long-term perspective

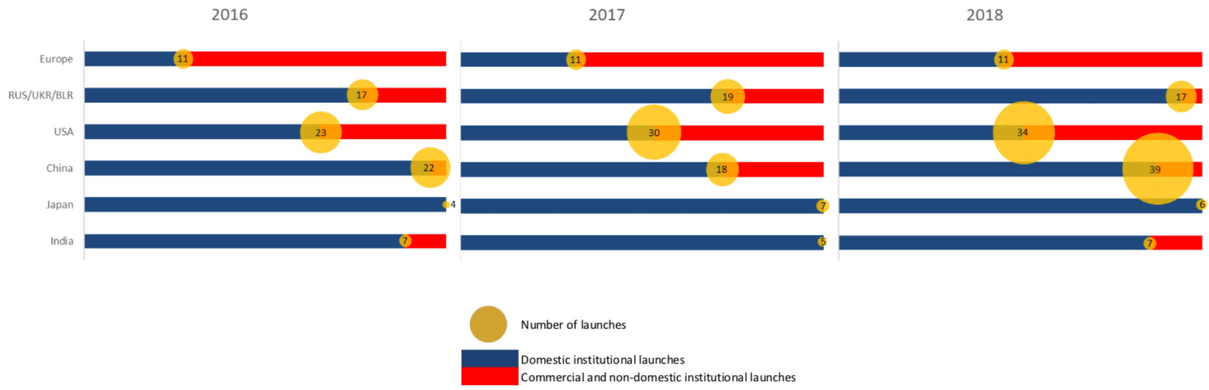

Figure U: Weight of institutional demand worldwide – detailed look

Another possible future is the SatCom operators will start orders of satellites and launch services as their fleets approach end of life. In this case, it is likely that electrical propulsion will drive the mass of the satellites.

Launch providers are facing fierce competition caused by the new entrants (Space X, Blue Origin) and possibly intensifying with the new launchers being developed and reused. Current focus is on 1st stage reusability which has proved doable, despite the commercial viability is yet to be proven. European industry maintains the position that in low volume production the reusability is not economical. So far, ESA limits its reuse programme on Prometheus demonstrator. In the European context, the British Skylon is the most advanced among the Europe-based private endeavours, in terms of TRL.

Yet another trend is the emergence of micro launchers. None is yet commercially successful, however around a hundred of companies is working on various concepts at different TRLs. Micro launchers are likely to be more expensive then launch service using aggregates o rideshare, but might be attractive in terms of availability and quality of service.

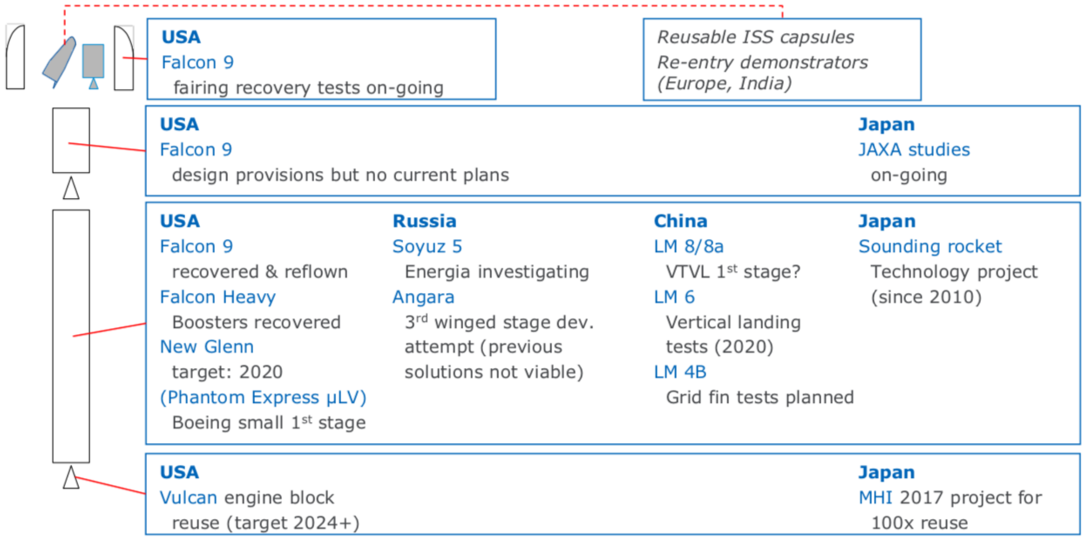

Figure V: Decline in GTO commercial launch services contracts signed

Five agencies/countries are preparing major evolutions of their launch vehicles. Ariane 5 launcher is Europe's prime launcher with proven track record of successful launches, however its expensive yet too-cheap-to-make-profit pricing causes financial difficulties to Arianespace, its operator. Recalling that Ariane 5 was not developed to serve GTO market (it was intended for Hermes spacecraft) while today GTO is by far its most usual target, the launcher has to face the fact that it is too powerful (therefore too expensive) to launch single satellite to GTO solution in terms of dual launch capability is being used for years but still the cost has become non-competitive. ESA therefore initiated development of Ariane 6 to address the cost of recurrent production and operation of the launch system. Ariane 6 uses synergies with Vega C, notably the P120C booster of Ariane 6 that is also main stage of Vega C. Overall the Ariane 6 design is rather conservative evolution of Ariane concept with very limited introduction of breakthrough technologies or processes. This potentially makes the launcher vulnerable to future market evolution.

Introduction of Ariane 6 went hand in hand with the change of governance whereby the less powerful two-boosters-equipped Ariane 62 serves the European institutional needs and heavy Ariane 64 is aimed at commercial GTO mission. The governance model adopted in 2014 assumed that ESA and other European institutions guarantee certain number (5) of launches per year and the industry is free in its decisions of the commercial exploitation of the Ariane 6 launcher while it accepts all the risk linked to exploitation. Due to unfavourable evolution of the GTO market in the past years, it is unlikely that the industry will bear its commitment. Some form of stepping in of ESA at Space19+ at latest seems inevitable. The likely approach to be taken is a Transition scenario based on buyout of number of first Ariane 6 launchers for European institutional use thus overcoming the lack of demand on commercial market and supporting the transition (notably the rump-up cost) while at the same time using the argument of de facto fully funding the transition phase to get in-depth visibility and control over the production cost including subcontracting.

Czech Republic

The Czech Republic has established itself in several areas in the development programme. It is involved in the production of Ariane 6 boosters and launch base construction. For Vega launcher the major achievement is the integrator role of the dispenser of small satellites and development of turbopumps and valves technology.

There are also several preparatory projects being funded with the expectations to master new technologies that will be later applied to new generation of European launchers such as thermoplast welding, tank insulation, structural health monitoring, ultra-wide band wireless communication, software for clean space applications, pyrotechnic separation, acoustic load and flutter analysis and last but not least sensing and vibration attenuation technologies can be taken as typical examples.

5) SPACE SITUATIONAL AWARENESS – SPACE SAFETY

Current situation

The general objective of the Space Situational Awareness (SSA) is to support independent utilisation of and access to space for research or services, through providing timely and quality data, information, services and knowledge regarding the environment, the threats and the sustainable exploitation of the outer space.

The SSA activities are enabling Europe to autonomously detect, predict and assess the risk to life and property due to remnant man-made space objects, re-entries, in-orbit explosions and release events, in-orbit collisions, disruption of missions and satellite-based service capabilities, potential impacts of Near Earth Objects, and the effects of space weather phenomena on space- and ground-based infrastructure.

There are two main SSA stakeholders in Europe, ESA with its SSA Programme and EU through SST Support Framework initiative.

Regarding the market perspective, it should be noted that the most of the SSA related services are being provided free of charge (not public, but open to stakeholders, satellite operators, scientific institutions etc.). In this regard, the SSA is presents mainly by the **Upstream** and **Midstream** market segments.

European SSA activities overview

In 2009, ESA established the SSA Programme as a European response to threats coming from outer space. In order to fulfil this objective, ESA's SSA Programme is focusing on three main areas:

- Space Weather (SWE): monitoring and predicting the state of the Sun and the interplanetary and planetary environments, including Earth's magnetosphere, ionosphere and thermosphere, which can affect space borne and ground-based infrastructure thereby endangering human health and safety.
- Near-Earth Objects (NEO): detecting natural objects such as asteroids that can potentially impact Earth and cause damage.
- Space Surveillance and Tracking (SST): watching for active and inactive satellites, discarded launch stages and fragmentation debris orbiting Earth.

The ESA SSA programme concluded its Preparatory Phase (SSA PP Programme, 2009-2012, envelope of €55 million) and Programme Period 2 (SSA P2, 2013-2016, envelope of €68.5 million). Actual programme period, Period 3 (SSA P3, envelope of €95.32 million), effective for 2017-2020, is running and focuses mainly on continuity and extension of ongoing activities (from SSA PP and SSA P2) and on the preparatory work on SWE mission to Lagrange point L5 (studies, pre-development of technologies etc.). The Czech Republic has subscribed €700 000 for SSA P2 and €2 million for SSA P3.

Involvement of Czech academia and industry in all three SSA domains (also incl. SWE Lagrange Mission activities) is well established, leading to an increase of expertise of involved entities.

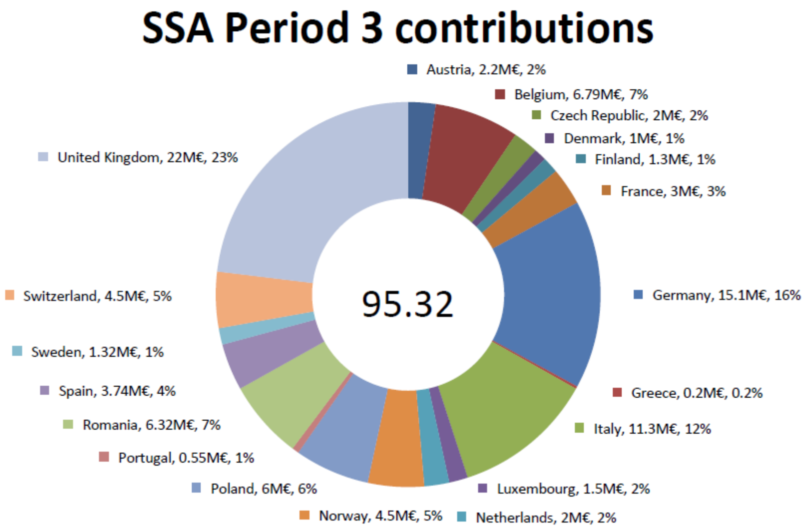

Figure W: SSA P3 Financial contribution by participating member states, source: ESA

EU has also turned its attention to SSA and particularly to the SST segment. In response to the proliferation of space debris and to the risk to the sustainability of space activities, it implemented an EU Space Surveillance and Tracking Support Framework (SST SF) in 2015 based on existing or future SST assets of several Member States (formed info a "SST Consortium", responsible for provision of SST Services). So far, however, SST assets available in Europe do not yet meet the required performance that would enable the provision of independent European SST data and services. Within this regard, possible extension of the EU SST SF by other activities related to the SSA is being negotiated at the EU level.

Trends

- SSA is emerging space sector, in the last few years, there is a significant increase of interest and funding of SSA area by national space agencies and other stakeholders worldwide.
- Regarding the increasing number of satellites and other space infrastructures orbiting the earth, there is a significant lack of high quality and consistent SST and SWE data while setting clear STM rules.

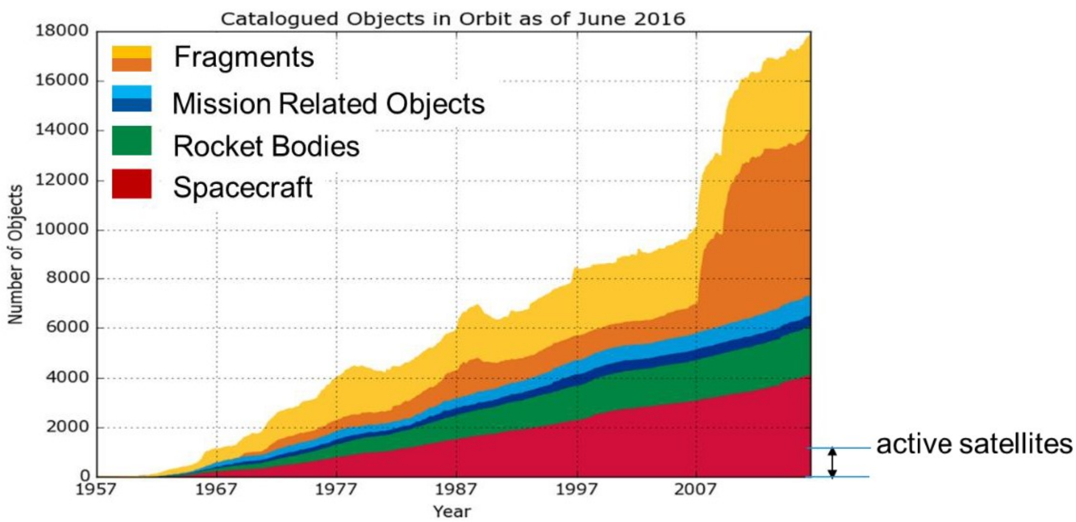

Figure X: Count evolution of space debris larger than 10cm orbiting the Earth, source: ESA[25]

- Regarding current international trends, NEO activities will be shortly complemented by asteroid deflection demonstration missions (e.g. HERA, DART etc.).

[25] ESA Space Safety Proposal (2018)35.

- ESA has the intention to rearrange existing SSA programme into new Space Safety Programme (i.e. continuity of current SSA activities and its extension by Planetary Defence activities, development of Space Vehicle Servicing technologies, aspects of Space Traffic Management, space debris mitigation via Clean Space initiative etc.). The intended Space Safety Programme should increase the current level of funding of SSA related activities by more than 5 times.

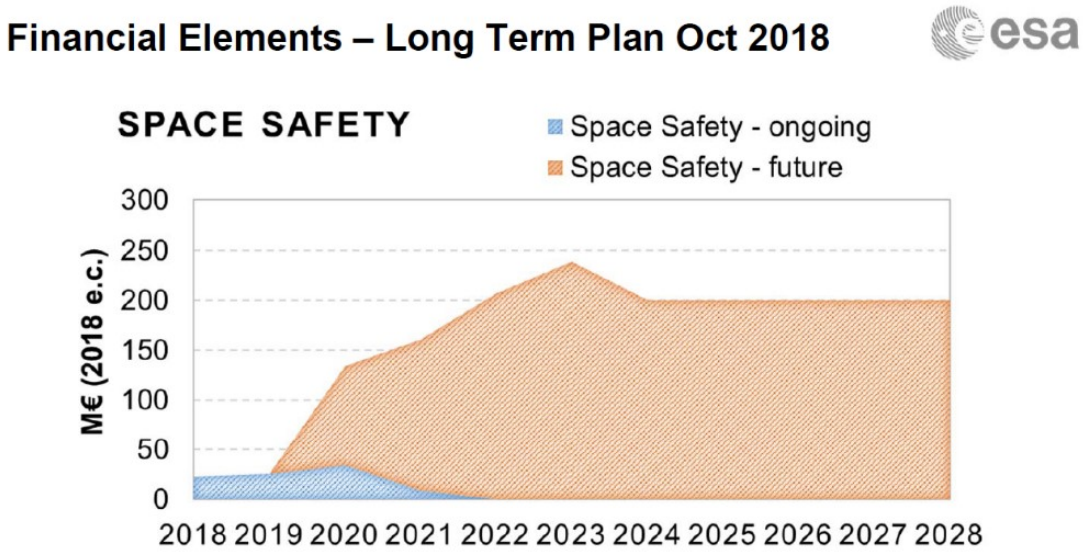

Figure Y: Intended funding level of ESA´s Space Safety Programme compared to the ongoing activities carried out under ESA SSA P3, source: ESA[26]

- European commission has the intention to increase level of funding of the EU SST SF and transform existing SST platform into SSA platform.
- Global approach to enhance international cooperation, collaboration and data sharing in all SSA domains.

Czech Republic

The Czech Republic, given its long-standing space heritage, is already taking active part in both the SSA Upstream and Midstream segment. The **Upstream** is mostly based on the delivery of SSA ground and space based related hardware, like a sensors, optics etc. while in the **Midstream**, Czech Industry and academia are focused on provision of daily based observations and analysis of NEO, SWE and SST phenomena (monitoring, modelling, characterisation, scientific analysis), scientific studies or specific SW development and data analysis. In the view of the intention to increase level of funds of the European SSA environment, SSA activities represent another promising space sector in which the Czech Republic can actively shape itself.

6) HUMAN SPACEFLIGHT, MICROGRAVITY AND EXPLORATION

Current Situation

In human spaceflight, microgravity and exploration the market is driven by institutional needs despite private investors are entering the scene with bold plans and sometimes lavish funding.

Historically human spaceflight has been a nationalistic governmental activity, later becoming less nationalistic (Interkosmos programme, joint Apollo-Soyuz mission, various bilateral and multilateral programmes), but still governmental. The international cooperation culminated in 1998 with launch of ISS which is still operational. Since ISS completion of ISS, two major changes can be observed. First, there is high interest in international collaboration among the leading space agencies (except for China where this is limited) in other space endeavours. Second, there has been a gradual movement towards more commercial solutions, including outsourcing of orbital cargo operations that is already a reality and orbital crew operations that is coming soon. In the short term, commercialization of space station

[26] Source: ESA, presentation of the Draft ESA LTP 2019-2028.

operations is foreseen as well as a private space tourism related-endeavours, and, in the longer term, large commercial ventures targeting business operations on the Moon, Mars and asteroids.

Space exploration investments globally were \$13.8 billion and \$14.6 billion in 2016 and 2017 respectively with U.S. contributing 74 % to this total. This sum includes in particular orbital infrastructures, Moon and Mars exploration, other deep space missions and related space transportation. Private sector is more and more engaged in space exploration – both start-ups and corporations. Agencies seek opportunities to enter in partnerships with private entities to leverage their investments and reach their objectives with better cost efficiency and promise of sustainable space exploration. Number of New Space companies has been established and first evidences of success have been demonstrated. Among them the most prominent being SpaceX, Blue Origin, Virgin Galactic and Stratolaunch that have the common denominator of being funded by high net-wealth individuals that provides number of advantages as well as certain fragility as seen in the case of the latter. Some (SpaceX, in particular) has accumulated enough expertise and managed to build strong industrial base and income flow that made them strong contender to space corporations established in the field for decades. Still, it is exactly this fragility (along with political reasons of supporting the respective voters of involved congressmen) that discourages NASA from turning to these new entrants of space exploration arena and turning down the SLS/Orion. At the same time, the resources of some of the entrants (Bezos, in particular) are such that it can singlehandedly reverse the exploration means and set new trend. Conservative commentators tend to advocate the cautions approach to continue with SLS-based exploration roadmap and re-evaluate only once the New Space companies prove themselves.

Human spaceflight is dominated by the ISS in low Earth orbit (LEO) which, today, is the only destination that astronauts can reach. Critics say that given the budgetary constraints of public human spaceflight, the current way of ISS operations must be abandoned and research focus shifted toward long-term spaceflight beyond LEO to study among others radiation effects and long-term microgravity exposure of humans.

ISS remains to be the highlight of the microgravity research and by far the strongest magnet for microgravity research funding when compared to other microgravity research platforms e.g. drop towers, parabolic flight, sounding rockets or free fliers.

There are a number of international platforms existing to exchange plans and policies as well as to coordinate exploration endeavours. The International Space Exploration Forum (ISEF) fosters political-level dialogue. Coordinated among national agencies is pursued by the International Space Exploration Coordination Group (ISECG) that published in 2018 the Global Exploration Roadmap (GER) as its key output. GER builds of sequencing of LEO, Moon and Mars missions – both robotic and human. The International Mars Exploration Working Group (IMEWG) has the aim to define internationally accepted reference Mars sample return mission.

Trends

The global investment in space exploration grew in the last years and is expected to pass \$20 billion by 2027.

ISS is almost completed (with very few non-essential elements still to be installed) and its lifetime was extended till 2024. From the technical point of view, further extension of ISS is feasible through re-certification of its various elements, however discussions are under way whether or not further extend its operations and (mainly) US President pushes towards commercial utilization and outsourcing of operations. The need for human presence in LEO is being disputed as the global focus is shifting from LEO to deep space – not only for reason of Moon and Mars exploration per se, but also because many voice concerns that the research beyond-LEO is much more pertinent. Despite NASA human spaceflight interests are turning from LEO towards Moon, in particular to and Lunar Orbital Platform – Gateway (LOP-G) at near-rectilinear halo orbit (NRHO), approval of such programme might be difficult due to opposition in US Congress that protects ISS related jobs (ISS consumes over \$3 billion per year in NASA funding). The latest major development in US was the announcement of aggressive timeline of Artemis programme to return humans on lunar surface.

ESA's human spaceflight budget is focused on ISS and most of it is spent on designing and building the MPCV-ESMs (Orion service module) for NASA as an in-kind contribution (barter) in exchange for ESA's share of ISS operating costs. Further, ESA seeks valuable contributions to the LOP-G to secure is role as global partner in Moon exploration. LOP-G and Moon habitats and rovers are adaptable for Mars missions which make ESA's role in LOP-G an entry ticket to Mars exploration.

Russia is facing budgetary cuts and contemplates about operating its own space station, most likely reusing Russian segment of the ISS.

Chinese ambitious and highly successful human spaceflight programme is managed by the Chinese military and is considered defence expenditure. It includes series of space stations and later mission to Moon with landing in 2030 timeframe. However, no international partner is foreseen to join in these endeavours despite sporadic partnerships for ground based training or experiments are being pursued by agencies.

In terms of destinations of interest, the government investments are converging towards Moon. Euroconsult forecast Prospects for Space Exploration 2027[27] compares 6 Mars missions in 2008-2017 time frame to 10 Mars missions in 2018-2027 time frame vis-à-vis 8 lunar missions in 2008-2017 time frame to 50 lunar missions in 2018-2027 time frame. Even when considering 50 mission over-optimistic the trend is still quite apparent.

Czech Republic

The Czech activities in this domain are limited on experiments at ISS, research in psychological and sociological aspect of human spaceflight and development of platform systems and instruments for robotic exploration missions.

7) SPACE SCIENCE

Current Situation

In the field of fundamental research, the scientific study and exploration of space is dominated by government funded activities. Since the beginning of space era, this traditional domain of space activities has constituted an important part of any national or international space programme and major space agencies allocate a significant fraction of their budgets to scientific missions. In financial year 2019, NASA allocated $5.9 billion to science programme, representing 28 % of its total budget (compare to $4.9 billion representing 30 % of its total budget in financial year 2013 as of 2014 NSP).[28]
In the same year, ESA's allocation to Science Programme (€507.4 million) and Mars (Aurora MREP and ExoMars and E3P ExoMars) and Moon (Luna-Resource lander) exploration (€123.7 million) amounted to about 11.3 % of ESA's total budget (compare to 15.1 % in 2013).[29] It is worth noting that the above ESA budget does not include the costs of scientific instrumentation and subsequent data analysis funded by national agencies of member states.

The segment of scientific space exploration is by its nature a non-profit activity with little to no direct commercial exploitation of its results. Nevertheless, scientific spacecraft are often highly technologically advanced, enter unexplored areas of space, and provide space validation and increase of TRL for new technologies with commercial potential. Scientific spacecraft and instruments are typically single purpose designed, but in some cases spacecraft platform segments (communication, power supply and distribution) as well as scientific instruments are being re-used with minor modifications on multiple missions. Wide international consortia and multi-agency missions are common in this domain. The worldwide spending in space science has stabilized in the $5-6 billion around 2010, but was predicted to grow to $9.6 billion in 2022.[30]

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[27] 2018 Brochure Prospects for Space Exploration – An economic & strategic assessment of the space exploration sector – Forecast to 2027 1st Edition A Euroconsult Executive Report http://euroconsult-ec.com/research/space-exploration-2018-brochure.pdf.

[28] NASA FYs 2028 and 2013 President's Budget Request Summary.

[29] ESA budget 2018 and 2013.

[30] EUROCONSULT 2013: Government Space Markets – World Prospects to 2022, The Space Industry's Essential Assessment of Government Spending in Space Applications, 4th edition.

Space science is a broad scientific discipline that encompasses astronomy, space exploration and study natural phenomena and physical bodies in outer space, such as space medicine and astrobiology, and many other fields. For the purpose of the NSP and its mapping of solar system exploration missions and technologies we distinguish engineering-driven human and robotic exploration such as ISS and ExoMars (further discussed in section 6) above, together with microgravity research) and science-driven exploration such as JUICE and Rosetta (further discussed in this section below). This division also respects how ESA is looking at exploration today. With this distinction, the space science can be broken down to the following general categories of space missions:

Solar System exploration missions: Missions to planets and other solar system bodies, including orbiters and landers, carrying a diverse payload composed of cameras, spectrometers, particle and electromagnetic sensors, etc. This category also includes missions studying the impact of solar activity on solar system and outer layers of Earth's atmosphere and magnetosphere. Examples include Jupiter Icy Moons Explorer JUICE (ESA), mission to Saturn Cassini with Titan lander Huygens (NASA-ESA), orbiters of planets of the inner solar system Mars Express, Venus Express and BepiColombo (ESA), ExoMars (ESA Mars landers, rover and orbiter), comet chaser Rosetta (ESA), missions observing the Sun and solar wind SOHO and Solar Orbiter (ESA) and missions investigating the Earth's magnetosphere, ionosphere, and upper atmosphere Van Allen Probes (NASA), Cluster (ESA) and TARANIS (CNES).

Astronomical and astrophysical missions: Earth orbiting spacecraft (or spacecraft orbiting Lagrangian points) carrying large telescopes designed for imaging of astronomical objects across the spectrum – from microwave to gamma ray wavelengths. Examples include gamma ray observatory INTEGRAL (ESA-NASA-Roscosmos), X-ray observatories XMM-Newton and ATHENA (ESA), UV to infrared Hubble space telescope (NASA-ESA), visible light observatory Gaia (ESA), decommissioned infrared telescope Herschel (ESA) and JWST (NASA-ESA) about to be launched, and microwave cosmic background observatory Planck (ESA). Telescopes specifically designed to observe exoplanets such as PLATO or CHEOPS (both ESA) also falls in this category.

Fundamental physics missions: A diverse category of missions performing fundamental physics experiments in space. A typical example are the MICROSCOPE (CNES-ESA) satellite to test the equivalence principle or LISA Pathfinder and the planned LISA missions (both ESA) dedicated to detect and accurately measure gravitational waves and in case of the LISA Pathfinder to test the ultra-high precision laser interferometry in space making sure LISA mission is feasible.

Trends

In European context the Cosmic Vision of ESA (with an approximate budget of €500 million per year) is the most significant programme in the area of scientific space exploration, being a part of the mandatory Science Program. The continuation of the programme beyond 2035 has been discussed from August 2018 to February 2019. In the framework of this programme ESA issues periodic calls for mission proposals divided into M-class (~€0.5 billion) and L-class (~€1 billion) and implements the selected candidates. The most recent Cosmic Vision mission with substantial Czech scientific participation is M2 Solar Orbiter (solar observatory approaching the Sun from a close distance – to be launched in 2020), however Czech scientist are successful to embark on almost every mission of the Cosmic Vison programme.

It has been observed that selections of M- and L-class mission were perceived by the scientific community as a fierce competition between various space science disciplined because eventual non-selection had long-lasting negative impact of the discipline. Thus for the most recent L missions ESA took a different approach. First, one theme per flight opportunity was selected in an open call. Than proposals for particular mission will be solicited restricted by the selected theme. This way mission selections are not providing expectations (and later disappointment) across vast scientific community. At the same time the intra-discipline competition is expected to lead to better mission proposals.

The next planning cycle of the ESA Science Programme, Voyage 2050, is now underway. In keeping with the bottom-up, peer-reviewed nature of the Science Programme, the definition of the next plan relies on open community input and on broad peer review. The community input will be gathered through the Call for White Papers, while the peer review of this input will take place through a two-tiered committee structure, with a Senior Committee of 13 European scientists supported by a number of Topical Teams. Members of Senior Committee and Topical Teams are appointed by the ESA Director of Science. The work of the Senior Committee started in late 2018 and will end in mid-2020.

The optional programs of ESA are relevant to space research (note that microgravity research and human spaceflight is covered in the previous section) are robotic exploration programmes Aurora and E3P plus PRODEX. The Aurora programme was formed with focus on Mars exploration, in particular on the ExoMars mission (both 2016 and 2020) and preparation of future Mars missions including the ultimate goal of the Mars the sample return (MSR) mission while Moon acted as a stepping stone. The E3P programme since 2016 encompasses all exploration-related activities of ESA implemented as optional programmes. As such it also has absorbed ExoMars. The PRODEX programme provides a framework for development of space-based scientific experiments and instrumentation (typically an instrument development is not included in ESA programs).

In global context, NASA and other space agencies (such as Roscosmos, JAXA or Chinese CNSA) possess rich scientific programs and joint missions between ESA and the respective agencies are common. CNSA is actively seeking a joint Chinese-ESA missions. On the contrary, NASA has withdrawn its planned contribution to the joint two-spacecraft ExoMars programme and joint two-spacecraft Jupiter moons mission (EJSM – the predecessor of the selected JUICE mission) due to budget cuts. Such withdrawals severely impact the whole missions and for this reason ESA established a policy for all its future joint missions not to accept junior partners with higher than 20 % involvement. Japanese space agency JAXA currently participates in BepiColombo, a joint ESA-JAXA mission to Mercury.

Many nations show increase interest in lunar exploration. Apart from the Artemis programme, several lunar landers are planned followed by Russian sample return mission and Chinese manned mission. European participation in these activities is likely to be very limited due to low affordability of Europeans space faring nations, due to financial burden of running programmes (ExoMars, ISS) and higher priorities (new Ariane 6 launcher).

In the recent months and years there is apparent and increasing interest in exoplanets which is further boosted by media. In the European context, both the S1 mission CHEOPS and M3 mission PLATO are contributing to this field.

Czech Republic

Significant activities of Czech subjects in space exploration exist in the domain of development of scientific instrumentation. Several research groups at the Czech Academy of Sciences have actively joined the preparation of ESA's Voyage 2050, which will define the long-term outlook of scientific missions for upcoming decades. White papers have been formulated and technical challenges explored in order to inform the industrial partners about new directions.

Apart from direct hardware contribution to spacecraft, Czech research institutions are the end users of scientific data obtained by many scientific missions with or without Czech hardware participation. Institute of Atmospheric Physics of the CAS also operates a telemetry station Panská Ves where data from several scientific spacecraft such as Cluster (ESA) and Van Allen Probes (NASA) are currently being received. Czech academia also significantly contributes to scientific preparation of planned missions, for example by simulations of various detector parameters with aim to define necessary features to achieve scientific excellence.

Czech scientific institutes and universities also actively participate in consortia proposing new missions, especially in ESA calls.

B. THE REVIEW OF THE NATIONAL SPACE PLAN 2014 – 2019

Historically second NSP was approved by the Government of the Czech Republic in October 2014 (i.e. 2014 NSP).[31] MD was responsible for elaborating and delivering the document to the Government of the Czech Republic. The document was prepared in cooperation with other Czech ministries, ESA, academia and industry.

The 2014 NSP identified long-term vision. In order to ensure that the Czech Republic is on the way to accomplish the vision the 2014 NSP defined the following mid-term objectives to be implemented by 2019:

- *Czech investment in space has an appropriate return.*
- *The Czech Republic has the necessary competences (industrial, academic, project management) and infrastructures exist to sustain the long-term vision.*
- *The objectives of 2016 were very successful (they have been achieved in 2013) however this success is sensitive to single Czech entities – for this reason the depth of industrial participation of Czech companies must be increased.*
- *The interaction between academia and industry is well balanced respecting their specific missions and roles.*
- *Czech companies have a sustained presence in the supply chain of European space industry.*
- *The Czech Republic recognizes space as a strategic element of national policy and has the effective tools to implement it.*

To evaluate whether the mid-term objectives were achieved in 2019 quantifiable evaluation criteria were set-up:

- *The contribution to ESA optional programmes (excluding PRODEX) is at least twice as high as the mandatory contribution and an overall return-on-investment (economic impact factor) on such ESA contributions including mandatory activities of a factor of 2.*
- *Balanced participation of academia and industry in space projects with at least 90 % of the budget of the ESA mandatory activities and optional programmes (excluding PRODEX) spent in Czech industry respecting the ratio spent by ESA in European space industry.*
- *At least one incubation scheme and associated technology transfer being implemented.*
- *At least one Czech Co-PI in a space-based scientific instrument assuming the funding of the payload projects of space missions is stable and sustainably growing.*
- *A minimum of one Czech-owned-IPR sustainable space product being supplied or about to be supplied.*
- *At least two companies that are suppliers to European primes and 3 companies supplying European sub-primes in sustainable fashion.*
- *A formalized training support scheme exists and space engineering competences in Czech university degrees were introduced.*
- *The Czech Republic has a formalised national space agency with clear competences, tools, budget and resources to implement the NSP, including a national space programme.*

1) *The contribution to ESA optional programmes (excluding PRODEX) is at least twice as high as the mandatory contribution and an overall return-on-investment (economic impact factor) on such ESA contributions including mandatory activities of a factor of 2*

This evaluation criterion reflects the mid-term objective "Czech investment in space has an appropriate return" and "The Czech Republic recognizes space as a strategic element of national policy and has the effective tools to implement it".

In order to ensure optimal geographical return of the Czech contribution to ESA and based on it also high return-on-investment, the Czech Republic needed to fund such ESA optional programmes which help to overcome "valley of death" and enable Czech industry to mature their technologies to be able to put them on the market. As far as the absorption capacity of Czech industry and academia allows, it

[31] Resolution of the Government of the Czech Republic No. 872 dated on 27 October 2014.

goes that bigger contribution to ESA optional programmes brings higher geographical return from ESA Mandatory Activities and bigger benefits for economy.

Since the membership in ESA brings the main opportunities for the Czech Republic in space and since the geo-return principle exists solely in ESA, the Czech participation in ESA activities and programmes have to be considered as a backbone for the calculation of the return of public investment in space in general.

a) The contribution to ESA optional programmes (excluding PRODEX) is at least twice as high as the mandatory contribution

Over the six years, the overall contribution to ESA optional programmes was being increased thanks to contribution of the MD. The substantial increase was materialised in 2017 and since then the level of funding remained stable. Average ratio between contribution to ESA mandatory activities and optional programmes excluding PRODEX is 2.03. This ratio for 2019 is 3.22.

On the other side, the increase of funding came relatively late to generate higher impact, i.e. three years later than originally planned. Only higher funding of ESA optional programmes and establishment of CF3PP enabled implementation of bigger projects with higher potential of return-on-investment. Such project could have started no earlier than in late 2017.

	2014	2015	2016	2017	2018	2019
Mandatory activities	**7 384 953 €**	**7 604 689 €**	**7 567 376 €**	**7 642 355 €**	**7 263 752 €**	**7 335 686 €**
Optional projects (total)	*6 497 434 €*	*6 545 564 €*	*10 757 520 €*	*25 058 165 €*	*27 140 730 €*	*25 785 482 €*
PRODEX	*1 500 000 €*	*1 500 000 €*	*1 500 000 €*	*2 200 000 €*	*2 200 000 €*	*2 200 000 €*
Optional projects (excluding PRODEX)	**4 997 434 €**	**5 045 564 €**	**9 257 520 €**	**22 858 165 €**	**24 940 730 €**	**23 585 482 €**
Ratio:	**0,68**	**0,66**	**1,22**	**2,99**	**3,43**	**3,22**
Average ratio:	**2,03**					

b) An overall return-on-investment (economic impact factor) on such ESA contributions including mandatory activities of a factor of 2

The Czech Republic emphasized the need to maximize the return of public investments to space activities as a cross-sectional principle of the whole 2014 NSP.

According to ESA statistics, the Czech Republic is achieving the geographical return at the level of coefficient 0.91-0.93 with slightly upward trend. Concerning the return-on-investment, the return-on-investment assumption made in 2014 during preparation of 2014 NSP calculated with an increase of contribution to ESA optional programmes which happened only in 2017. However, MD prepared a study for MF in 2016 which analysed around 90 business cases to estimate expected return-on-investment effects on both space and non-space sector. The study showed that expected return-on-investment of the contributions of the Czech Republic to ESA which had been made or should be made is of a factor of 9.24. It should be noted that the said return on investment is calculated using incomplete data due to still on-going development in majority of the cases. Such data tend to be biased due to inherent optimism of questioned companies and their tendency to underestimate risk. Having risk accounted for, the return on investment shall always be lower, hence the factor of 12.22 needs to be seen as upper bound rather than the target.

The updated study for 2019 analysed 140 business cases and showed that expected return-on-investment stemming from contributions of the Czech Republic to ESA which have been made or which should be made is 8.5. This factor seems to be more realistic taking into account additional experience of Czech companies have gained since 2015. Czech academia activities are not included in both calculations.

2) ***Balanced participation of academia and industry in space projects with at least 90 % of the budget of the ESA mandatory activities and optional programmes (excluding PRODEX) spent in Czech industry respecting the ratio spent by ESA in European space industry***

This evaluation criterion reflects the mid-term objective "The Czech Republic has the necessary competences (industrial, academic, project management) and infrastructures exist to sustain the long-term vision" and "The interaction between academia and industry is well balanced respecting their specific missions and roles".

As stated in 2014 NSP, just before the accession of the Czech Republic to ESA, the participation of academia in space projects was far higher that the participation of industry. However, ESA activities reflect very different distribution of funds between academia and industry. The usual participation of industry in ESA activities represents 90-95 % of overall budget spending for ESA projects.

This evaluation criterion is of particular importance to achieve an optimised distribution of funding to maximize the ESA geo-return in the Czech Republic. While the evaluation of similar criterion in 2010 NSP was based on CIIS, which was implemented during first six years of the Czech Republic membership in ESA, the actual evaluation criterion takes into account all projects implemented in ESA so far. According to a study made to this purpose in 2019, 89.8 % of the budget of the ESA Mandatory Activities and optional programmes (excluding PRODEX) since the accession of the Czech Republic to ESA has been spent in Czech industry. However, if the C3PFP is included in the calculation, this ratio rises to 91.3 %.

3) ***At least one incubation scheme and associated technology transfer being implemented***

This evaluation criterion reflects the mid-term objective "The Czech Republic has the necessary competences (industrial, academic, project management) and infrastructures exist to sustain the long-term vision" and also partially supports other mid-term objectives.

The Czech Republic joined the European-wide ESA BIC network in 2016 by establishing ESA BIC Prague. In 2018, ESA BIC Prague branch in Brno was open. The operator of ESA BIC Prague is CzechInvest. MD, MPO, Capital City of Prague, South Moravian Region and South Moravian Innovation Centrum (JIC) are its main partners. The ESA BIC provides financial, technical and business support with aim to turn innovative business concepts, using space technologies into successful businesses. The actual plan is to incubate 25 companies in Prague and 9 companies in Brno by 2021. ESA BIC Prague has already had its few alumni and its success rate is 100 % so far.

The Czech Republic also joined the ESA Technology Transfer Network in 2015. The network consists of brokers across Europe who are working to identify novel uses for technology that has been developed as part of the ESA space programme. They are also interested in identifying technologies in other sectors that could benefit the exploration and utilisation of Space. The operator of ESA Technology Transfer Broker in the Czech Republic is the Technology Centre of CAS.

4) ***At least one Czech Co-PI in a space-based scientific instrument assuming the funding of the payload projects of space missions is stable and sustainably growing***

This evaluation criterion reflects the mid-term objectives "The Czech Republic has the necessary competences (industrial, academic, project management) and infrastructures exist to sustain the long-term vision" and "The interaction between academia and industry exists and is well balanced".

The PRODEX programme is the financial tool to implement payload projects of space missions. The funding of the PRODEX programme can be considered as stable and growing (see table):

	2014	**2015**	**2016**	**2017**	**2018**	**2019**
PRODEX	€ 1 500 000	€ 1 500 000	€ 1 500 000	€ 2 200 000	€ 2 200 000	€ 2 200 000

There is a running (2019) project on development and implementation of Low Frequency Receiver module of the Radio & Plasma Wave Investigation (RPWI) instrument for JUICE mission.

The JUICE spacecraft will provide a thorough investigation of the Jupiter system in all its complexity with emphasis on the three ocean-bearing Galilean satellites, and their potential habitability. JUICE has been tailored to observe all the main components of the Jupiter system and untangle their complex interactions.

RPWI consists of a highly integrated instrument package that will carry out comprehensive measurements of the local space environment as well as monitoring radio wave emissions in the Jovian system.

There is 25 universities and scientific institutes participating on this project, from which is 5 Co-PIs, with Institute of Atmospheric Physics of CAS among others.

In 2015, Institute of Atmospheric Physics, Czech Academy of Sciences has also been selected by ESA as a PI institution of the Wave analyser module in the MAGRET instrument for the ExoMars 2020 surface platform.

This criterion has been successfully met.

5) ***A minimum of one Czech-owned-IPR sustainable space product being supplied or about to be supplied.***

This evaluation criterion reflects the mid-term objectives "The Czech Republic has the necessary competences (industrial, academic, project management) and infrastructures exist to sustain the long-term vision" and "The depth of industrial participation of Czech companies must be increased".

An SME company based in Brno has developed a complex small satellite dispenser, a mechanism to deliver multiple satellites into orbit on top of the Vega launcher. The Proof of concept flight is scheduled for second half of 2019 and the flight

6) ***At least two companies that are suppliers to European primes and 3 companies supplying European sub-primes in sustainable fashion.***

This evaluation criterion reflects the mid-term objectives "The Czech Republic has the necessary competences (industrial, academic, project management) and infrastructures exist to sustain the long-term vision" and "Czech companies have a sustained presence in the supply chain of European space industry".

The above-mentioned SME became supplier of the dispenser to prime contractor of Vega launcher. Another SME managed to establish itself as supplier of Eurostar Neo EGSE to one of the Neosat primes.

Three different Czech companies build capacities to deliver precisely manufactured parts and mechanisms, segments of flame detector and large launcher assemblies. Customers of the first oneare variety of foreign system and subsystem integrators. The second is positioned to deliver replacement segments to space port operator for Ariane 6 launch pad maintenance. The third delivers it assemblies to the manufacturer of P120C solid rocket boosters.

7) ***A formalized training support scheme exists and space engineering competences in Czech university degrees were introduced.***

This evaluation criterion reflects the mid-term objectives "The Czech Republic has the necessary competences (industrial, academic, project management) and infrastructures exist to sustain the long-term vision" and "The depth of industrial participation of Czech companies must be increased".

Question of establishing a formalized training support scheme in space in the Czech Republic came up for discussion already during the CIIS period. No solution was found those times.

The discussion was re-enabled in 2017 when the C3PFP was prepared. One of three pillars of the C3PFP approved by the Government of the Czech Republic and also ESA Council aims at "the establishment of training schemes for graduates from the Czech Republic". The details are being defined by C3PFP Committee as of the second half of 2018.

On the other hand, a successful implementation of specific training support scheme can be found in several domains. In the area of primary and secondary education, the Czech Republic successfully implemented the ESA´s European Space Education Office (ESERO), with its goal to enhance young people's literacy in space science, technology, engineering and mathematics subjects and attract them to future careers in these fields. The ESERO Czech Republic, founded in 2015, has already supported more than 8.000 teachers and 270.000 students through 24 newly developed space-oriented educational programmes. Regarding the university education, new master study programme focused on formation of experts – engineers for aerospace, research and development and air transport was introduced and accredited in 2016.

Another training scheme, focused on young professional and business/start-up community, is represented by ESA BIC Prague complementary networking and skill-improving activities in a form of Hackathons, Space Nights, FuckUp Nights, competitions, festivals, etc. with its total outreach of about 70 000 people per year.

8) *The Czech Republic has a formalised national space agency with clear competences, tools, budget and resources to implement the NSP, including a national space programme.*

This evaluation criterion reflects the mid-term objective "The Czech Republic has the necessary competences (industrial, academic, project management) and infrastructures exist to sustain the long-term vision" and "The Czech Republic recognizes space as a strategic element of national policy and has the effective tools to implement it."

In 2011 the Government entrusted the MD with the task to coordinate all space activities in the Czech Republic. For better transparency and involvement of all stakeholders both from public and private sector the MD established the Coordination Council for Space Activities and its permanent Committees (Scientific Activities, Industry and Applications, Security and International Affairs). This coordination works pretty well.

A national space agency has not been established yet. However, there has been quite a lot of discussions among ministries over the years on whether to establish the national space agency or whether to continue with the present settings. Reluctance of certain ministries to transfer its competences and corresponding personal and financial resources to the agency showed up as the main difficulty to establishment of the national space agency. Also challenges how to coordinate boost in space downstream sector (i.e. market development and market uptake) which will be quite decentralised anyway and how to use and support synergies among technologies in aviation, space and defence overshadowed discussions about the establishment of the national space agency for the time being.

C. INTERNATIONAL AGREEMENTS AND TREATIES RELATED TO SPACE

1) International Treaties Related to Space

UN: (1) Treaty on Principles governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies; (2) Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space; (3) Convention on International Liability for Damage Caused by Space Objects (4) Convention on Registration of Objects Launched into Outer Space

ESA: (1) Convention for the Establishment of a European Space Agency; (2) Agreement between the Czech Republic and the European Space Agency concerning the Accession of the Czech Republic to the Convention for the Establishment of a European Space Agency and Related Terms and Conditions (3) Agreement between the States Parties to the Convention for the Establishment of a European Space Agency and the European Space Agency for the Protection and the Exchange of Classified Information

EU: Treaty on European Union and Treaty on the Functioning of the European Union

EUMETSAT: (1) Convention for the Establishment of a European Organization for the Exploitation of Meteorological Satellites (EUMETSAT); (2) Protocol on Privileges and Immunities of the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT); (3) Amending Protocol to the Convention for the Establishment of a European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)

ESO: (1) Convention establishing the European Organization for Astronomical Research in the Southern Hemisphere; (2) Agreement between the Government of the Czech Republic and the European Organization for Astronomical Research in the Southern Hemisphere concerning the Accession to the Convention Establishing a European Organization for Astronomical Research in the Southern Hemisphere and Related Terms and Conditions, (3) Protocol on the Privileges and Immunities of the European Organization for Astronomical Research in the Southern Hemisphere, (4) Agreement between the Ministry of Education, Youth and Sports of the Czech Republic and the European Organization for Astronomical Research in the Southern Hemisphere concerning the Payment Schedule of the Czech Republic for the European Extremely Large Telescope

Intersputnik: Agreement on the establishment of the International System and Organization of Space Communications

ECMWF: Co-operation Agreement between the European Centre for medium-range weather forecasts and the Czech Republic

EUROCONTROL: International Convention on Cooperation for the Safety of Air Navigation EUROCONTROL

WMO: Convention of the World Meteorological Organization

IMO: Convention on the International Maritime Organization

ICAO: Convention on International Civil Aviation

IMSO: (1) Convention on the International Mobile Satellite Organization; (2) Revised Protocol on the privileges and immunities of the International Mobile Satellite Organization

ITU: International Telecommunication Constitution and Convention

ITSO: Agreement relating to the International Telecommunications Satellite Organization

EUTELSAT IGO: Convention establishing the European Telecommunications Satellite Organization

2) Agreements on the Scientific and Technical Cooperation

List of states with which the Czech Republic (Czechoslovakia) has concluded an agreement on scientific and technical coopration

Afghanistan, Albania, Algeria, Angola, Argentina, Azerbaijan, Bangladesh, Belarus, Bolivia, Botswana, Bulgaria, Brazil, Cambodia, China, Chile, Colombia, Costa Rica, Cuba, Cyprus, Ecuador, Ethiopia, Finland, France, Germany, Ghana, Grenada, Grece, Guinea, Guinea-Bissau, India, Indonesia, Italy, Japan, Kenya, Komi, Korea, Kuwait, Laos, Libya, Hungary, Mali, Mexico, Morocco, Mozambique, Niger, Nigeria, Nicaragua, Panama, Pakistan, Peru, Philippines, Poland, Portugal, Romania, Rwanda, Slovakia, Slovenia, Somalia, Sri Lanka, Spain, Sweden, Syria, Tunisia, Ukraine, United Arab Republic, United

Kingdom of Great Britain and Northern Ireland, United States of America, Vietnam, Yemen, Yugoslavia, Zambia, Zimbabwe.

3) Agreements on the Economic Cooperation

List of states with which the Czech Republic (Czechoslovakia) has concluded an agreement on economic coopration:

Afghanistan, Algeria, Angola, Argentina, Bangladesh, Belarus, Benin, Brazil, Cambodia, China, Denmark, Ethiopia, France, Ghana, Guinea, India, Indonesia, Italy, Korea, Cuba, Malta, Myanmar, Germany, Nigeria, Nicaragua, Portugal, Saudi Arabia, Serbia and the Montenegro, South Africa, Sudan, Syria, Switzerland, Tunisia, Turkey, United Arabian Republic, Vietnam, Yemen.

D. Summary of proposed yearly Czech contributions to ESA

In line with the measures set out in chapter 5.3.5, Czech Republic's yearly contributions to ESA from 2020 to 2025 should amount at least to the following:

Programme domain	Type of programs	TOTAL	
		EUR	CZK
Earth Observation	Technology	€ 1 300 000	33 150 000,00 Kč
Earth Observation	Missions	€ 3 500 000	89 250 000,00 Kč
Earth Observation	Applications	€ 1 100 000	28 050 000,00 Kč
Telecommunications	Technology	€ 3 300 000	84 150 000,00 Kč
Telecommunications	Missions	€ 2 500 000	63 750 000,00 Kč
Telecommunications	Applications	€ 1 400 000	35 700 000,00 Kč
Satellite navigation		€ 800 000	20 400 000,00 Kč
General technology		€ 4 200 000	107 100 000,00 Kč
Launchers	Technology	€ 2 800 000	71 400 000,00 Kč
Launchers	Missions	€ 9 500 000	242 250 000,00 Kč
Human Space Flights, Microgravity and Exploration		€ 500 000	12 750 000,00 Kč
Space Safety		€ 3 500 000	89 250 000,00 Kč
Scientific Payload (PRODEX)		€ 3 200 000	81 600 000,00 Kč
Total ESA Optional Programmes		**€ 37 600 000**	**958 800 000,00 Kč**
ESA mandatory programmes and CSG		€ 7 800 000	198 900 000,00 Kč
C3PFP		€ 14 500 000	369 750 000,00 Kč
TOTAL		**€ 59 900 000**	**1 527 450 000,00 Kč**

Note: Exchange rate of 25.5 CZK/€ is used (based on ČNB prognosis of CZK/€ evolution from 1. 8. 2019).

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F. ACRONYMS

A/C	Aircraft
ALV	Association of Aerospace Manufacturers of the Czech Republic
AMSP	Association of Small and Medium-Sized Enterprises and Crafts of the Czech Republic
ARTES	Advanced Research in Telecommunications Systems
ASD	AeroSpace and Defence Industries Association of Europe
ATM	Air Traffic Management
B2B	Business-to-Business
B2G	Business-to-Government
CAS	Czech Academy of Sciences
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CENIA	Czech Environmental Information Agency
CERN	European Organization for Nuclear Research
CM	ESA Council at ministerial level
CMZR Bank	Czech-Moravian Guarantee and Development Bank
CNES	French National Space Agency
COI	Community of Interest
COPUOS	UN Committee on the Peaceful Uses of Outer Space
CSA	Czech Space Alliance
ČBÚ	Czech Mining Administration
ČMZRB	Czech-Moravian Guarantee and Development Bank
CSG	Centre Spatial Guyanais
ČTÚ	Czech Telecommunication Office
CTP	Science Core Technology Programme
CZEPOS	Czech network of GPS stations
C3PFP	Czech 3rd Party Framework Project
CZK	Czech Crown
EATMS	European Air Traffic Management System
EC	European Commission
ECI	European Component Initiative
ECMWF	European Centre for Medium-Range Weather Forecasts
ECSS	European Cooperation for Space Standardization
EDA	European Defence Agency
EDRS	European Data Relay System
EDRS	European data relay system
EE	Earth Explorer Component
EGAP	Export Guarantee and Insurance Corporation
EGEP	European GNSS Evolution Programme
EGNOS	European Geostationary Navigation Overlay Service
EGSE	Electronic Ground Segment Equipment
EISC	European Interparliamentary Space Conference
ELIPS	European Programme for Life and Physical Sciences and Applications in Space
EO	Earth Observation
EOEP	Earth Observation Envelope Programme
EOP	Employment Operational Programme
EPO	European Patent Office

EPS	EUMETSAT Polar System
ESA BIC	ESA Business Incubation Centres
ESA LTP	ESA Long-Term Plan
ESA	European Space Agency
ESERO	European Space Education Resource Office
ESIF	European Structural & Investment funds
ESO	European Southern Observatory
ESOs	European Standardization Organizations
ESTEC	European Space Research and Technology Centre
ETSI	European Telecommunications Standards Institute
EU	European Union
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EUR	Euro (€)
EUSC	European Union Satellite Centre
EUSPA	EU Agency for the Space Programme
FLPP	Future Launchers Preparatory Programme
GA CR	Czech Science Foundation
GDP	Gross domestic product
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GMDSS	Global Maritime Distress and Safety System
GMES	Global Monitoring for Environment and Security
GNI	Gross National Income
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSA	European Global Navigation Satellite System Agency
GSC	GMES Space Component
GSMC	Galileo Security Monitoring Centre
GSP	General Studies Programme
GSTP	General Support Technology Programme
GTO	Geostationary transfer orbit
HSNAV	Horizon 2020 Satellite Navigation Programme
CHMI	Czech Hydrometeorological Institute
ICAO	International Civil Aviation Organization
ICTs	Information and communication technologies
IMO	International Maritime Organization
IMSO	International Mobile Satellite Organization
INSPIRE	Innovation in Science Pursuit for Inspired Research
IP	Intellectual Property
IPR	Intellectual Property Rights
IROP	Integrated Regional Operational Programme
ISS	International Space Station
ITAR	International Traffic in Arms Regulations
ITI	Innovation Triangle Initiative
ITS	Intelligent Transport Systems
ITSO	International Telecommunications Satellite Organization
ITU	International Telecommunication Union
JAXA	Japan Aerospace Exploration Agency

LBS	Location-Based Services
LEO	Low Earth Orbit
LTCR	Long-Term Capability Requirement
LTDP	Long-Term Data Preservation Programme
MetOp	EUMETSAT Polar System
MetOp-SG	EUMETSAT Polar System Second Generation
MD	Ministry of Transport
MEMS	Micro-Electro-Mechanical Systems
MF	Ministry of Finance
MK	Ministry of Culture
MMR	Ministry of Regional Development
MO	Ministry of Defence
MPO	Ministry of Industry and Trade
MŠMT	Ministry of Education, Youth and Sports
MV	Ministry of Interior
MZe	Ministry of Agriculture
MZd	Ministry of Health
MZV	Ministry of Foreign Affairs
MŽP	Ministry of the Environment
MOP	Meteosat Operational Programme
MMR	Ministry of Regional Development
MREP	Mars Robotic Exploration Preparation
MSG	Meteosat Second Generation Programme
MSI	International Maritime Organization
MTG	Meteosat Third Generation
NAC	North Atlantic Council
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NEOs	Near Earth Objects
NG	Next Generation
NGP	Next Generation Platform
NOAA	National Oceanic and Atmospheric Administration
NSA	National Security Authority
NSP	National Space Plan
OBPS	On-board platform systems
OECD	Organization for Economic Co-operation and Development
OP PPR	Operational Programme Prague – Growth Pole of the Czech Republic
OP JAK	Operational Programme Jan Amos Komensky
OPE	Operational Programme Environment
OPC	Operational Programme Competitiveness
OPT2	Operational Programme Transport 2
PECS	Programme for European Co-operating States
PRODEX	Programme de Développement d'Expériences scientifiques
R&D	Research and Development
ROI	Return on Investment
RPAS	Remotely Piloted Aircraft Systems
RPAS	Remotely Piloted Aircraft Systems
S/C	Spacecraft

SARPs	Standards and Recommended Practices
SAR	Synthetic Aperture Radar (EO)
SAR	Search and Rescue Service (Galileo)
SBAS	European Satellite Based Augmentation System
SCOE	Special Checkout Equipment
SDT	Association for Transport Telematics
SESAR	Single European Sky Air Traffic Management Research
SME	Small and medium enterprises
Space19+	ESA Council at ministerial level in 2019
SSA	Space Situational Awareness
SST	Space Surveillance and Tracking
STEM	Science, Technology, Engineering and Mathematics
SÚJB	State Office for Nuclear Safety
SWE	Space Weather
TA ČR	Technology Agency of the Czech Republic
TPM	Third Party Missions
TRL	Technological Readiness Level
TRP	ESA’s Technology Research Programme
TTB	Technology Transfer Broker
TTP	Technology Transfer Programme
UNOOSA	UN Office for Outer Space Activities
ÚPV	Industrial Property Office
ÚV ČR	Office of Government of the Czech Republic
VHR	Very High Resolution
WMO	World Meteorological Organization
WRC	World Radiocommunication Conference
WTO	World Trade Organization
YGT	Young Graduate Trainee (Programme)