Assessment of the socio-economic impact of the ESA participation to the International Space Station (ISS) Programme

ESA reference:

ESA-IPL-PLH-MT-LE-2016-182

30 August 2016

Executive Summary

Prepared in cooperation with:

Introduction

The overall objective of the study is to undertake an exhaustive assessment of the socio-economic impacts of ESA participation to the ISS programme, comprising an evaluation of the economic (GDP) impact (direct, indirect and induced) as well as of catalytic and wider impacts associated to ISS exploitation, on the economies of the ESA Member States, along the same functional lines of what was achieved in the 2014 study carried out by Strategy& for ESA on the Socio-economic Impact of the Ariane 5 and Vega programmes.

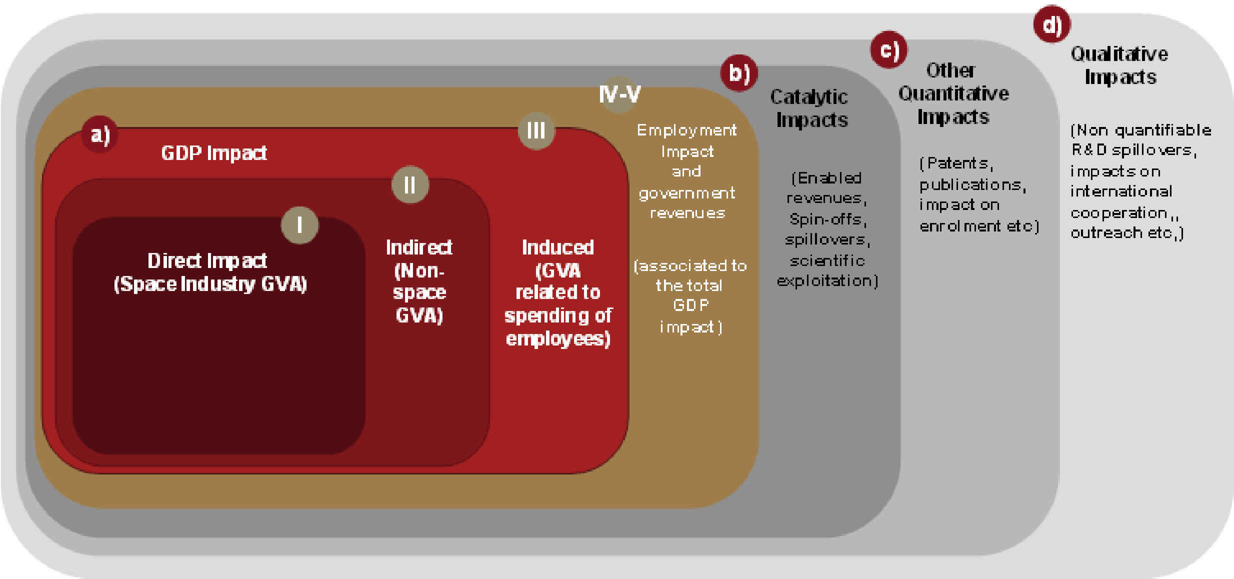


Figure 1 – Types of Impacts assessed in the study

The subject matter scope of the study is the entirety of ESA involvement into the ISS programme for the three areas: ISS development, ISS exploitation and ISS utilisation (ELIPS), **from 1995 (approval of ESA ISS programme) to current (2015/17 given the ISS Exploitation phase 2)**. Specifically, as per terms of reference, the study has the following main objectives:

- The **primary objective is to evaluate ex-post the overall spectrum of socio-economic impacts associated to ESA participation in the ISS programme** (ISS Development, ISS Exploitation and Utilisation (ELIPS)) on participating member states; this includes the following:

  - **Economic (GDP) impact assessment**, comprising direct, indirect, and induced impacts on gross value added in participating member states, together with direct and indirect employment impacts, and government – tax – revenues associated with the increased economic activity brought upon by ESA spending in the programme
  - **Catalytic and wider impacts assessment**, i.e. impacts associated to spin-offs and technology spillovers from development activities, and impacts associated to the exploitation of the ISS infrastructure (enabled revenues, scientific exploitation, wider qualitative impacts)
  - **Scenario analysis,** aimed at defining and characterizing a potential counterfactual scenario in order to ultimately provide an understanding of the actual benefits brought upon by ESA participation to the ISS (i.e. benefits that are net of opportunity cost)

- A **secondary objective is to evaluate ex-ante the potential impacts that may result from the participation of ESA to an extension of the ISS exploitation and utilisation programme** until 2024, on the basis on an extrapolation of the results obtained in the ex-post assessment

The assessment is ultimately aimed at providing hard evidence (figures) of the benefits accrued so far on member states and Europe at large from spending in the ISS programme (ex-post) and of future expected benefits from programme continuation (ex-ante), to serve as support in decision/policy making and in communication/outreach vis-à-vis member states, the wider stakeholder community and the general public.

The ISS Programme presents a multiplier of 1.8 which is at the upper end of the range of equivalent multipliers for manufacturing industries in Europe.

Quantitative analysis results.

The estimated value added (direct + indirect + induced) generated over the entire period (1995-2016) is EUR 14.6 B, while the total ESA funding is some EUR 8 B. This represents a **multiplier of 1.8** which is at the upper end of the range of equivalent multipliers for manufacturing industries in Europe. The incremental government revenues originating from the ISS programme amounted to some EUR 7 B in total over 1995-2016.

Relating the total value added impact to only the direct impact (EUR 5.1 B) gives a Type II multiplier of 2.86, with the Type II multipliers for most countries falling in the range of 2.0-4.0. This type of multiplier tends to be lower for high value-added sectors like space in which relatively more of the activity takes place within the industry itself rather than among suppliers. It does not indicate 'low impact', but rather a higher proportion of the impact falling within the sector in which 'direct' impact is measured.

The EUR 8 B invested in ISS over 1995-2016 is estimated to have boosted total employment by around 209,518 person years, with the additional employment in the space sector equivalent to 110,323 person years. As a result, the modelling showed an employment multiplier of 1.9 across the bloc of countries studied, with every 100 additional jobs created in the space sector supporting 90 additional jobs in the wider economy. Thus a notable employment impact was felt beyond the space sector.

Finally, some EUR 7 B were generated in governmental revenues over 1995-2016, thus 88% of the contributions of the Member States on the ISS Programme have been retrieved by governments through different types of taxes and social contributions.

Catalytic and wider impacts have been evaluated along four main dimensions: space technology, fundamental and applied research, inspiration, and strategic/international cooperation.

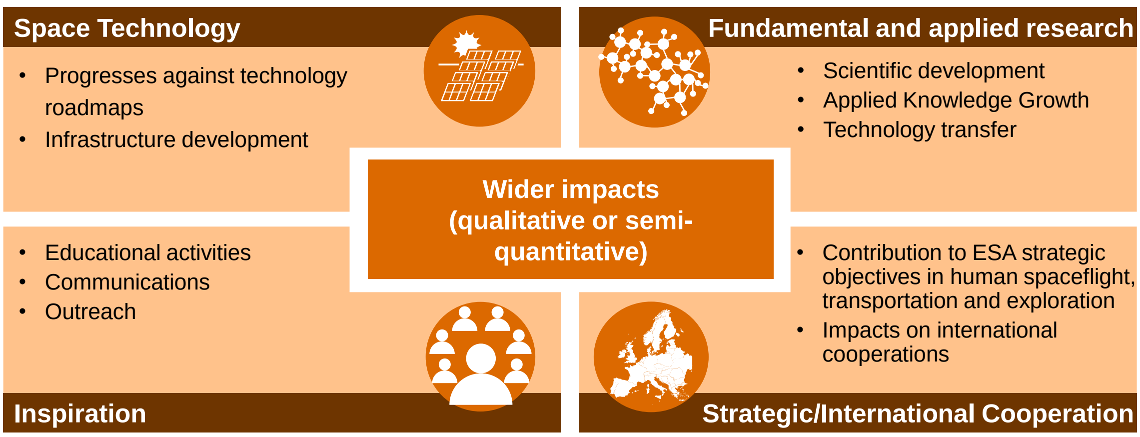


Figure 2 – Wider impacts considered in the study

The analysis of the qualitative impacts relies on an extended data consultation exercise with the objective to collect data points from relevant stakeholders. The sample of stakeholders interviewed within the study provided a very positive feedback concerning the ISS. This is especially true for the representatives of the Industry (both LSI and SME), and representatives of Research Centres and

Institutions. It shall be noted that the top-down approach is “success oriented” and therefore facilitates the identification of success stories and positive experiences within the interviewed stakeholders.

The figure below summarises the feedback of LSI, SME and Research Centres on the effect of their involvement in the ESA ISS programme on the number of new hires, the enhancement of the internal processes (management, engineering, manufacturing), the increased international exposure, and on the number of new engagements facilitated by the accumulated ISS expertise.

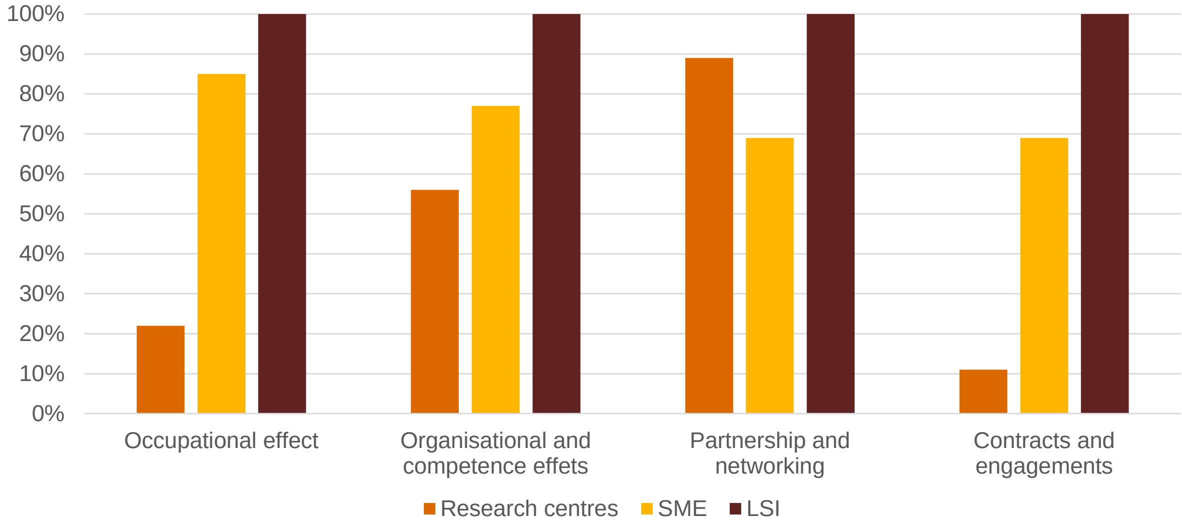


Figure 3 – Overview of stakeholder feedback on ISS generated benefits

Data gathered from interviewed Large Space Integrators, SMEs and Research Centres indicated an Enabled revenues multiplier of 2,20

Type of stakeholder	Multiplier	Type of enabled revenues
Research Centres	0,05	Annual
Small Medium Enterprises	0,47	Annual
Large Space Integrators	2,24	One-off
Aggregated	2,20	Annual/One-off

In the case of SMEs spin-offs and commercialisation of new products and services drives the vast majority of the enabled revenues. As we described in more detail in the final report, SMEs have often generated spin-offs dedicated to the commercialisation of the new products or services. As a consequence, the evaluation of the multiplier is based on actual and/or forecasted increase of the annual revenue attributable as a whole or as a part to the ISS participation.

The on-going international cooperation between agencies on the ISS has formed foundations to solid interagency relationships and ESA’s participation to the programme has proven Europe’s value as a viable partner.

ESA’s reputation has already led to several on-going partnerships beyond the ISS and multiple other partnership opportunities, which are highlighted in the table below.

	NASA	Roscosmos	CSA
LEO exploitation - post ISS		*OPSEK****	
Human missions beyond LEO	Orion MPCV*		
Robotic Moon exploration		Luna program**	
Robotic Mars exploration		ExoMars*	ExoMars*

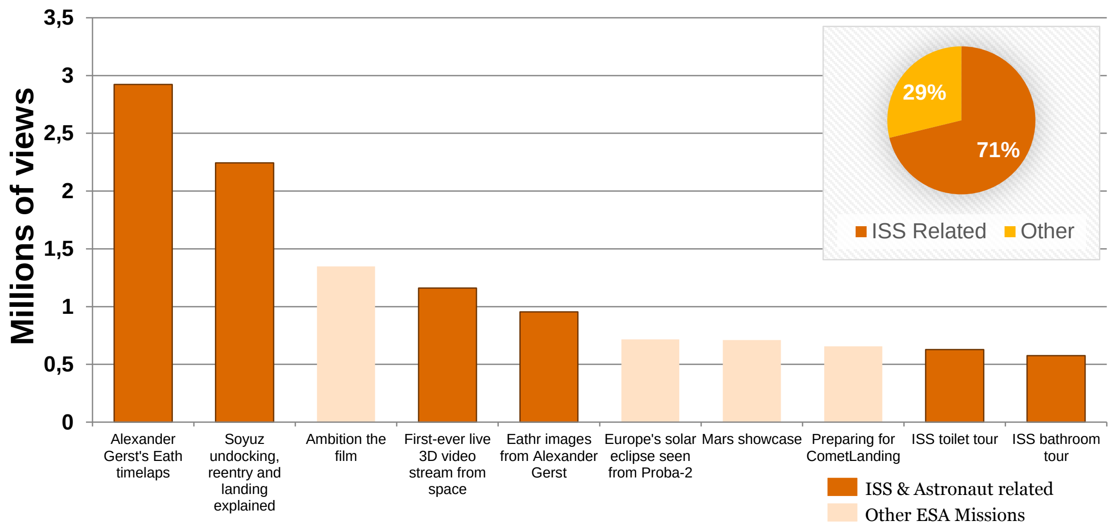
**on-going; **in preparation; ***potential*

The ESA Space Exploration Strategy defines the gradual pathway from the ISS to a human settlement on the surface of Mars, identifying four (intermediate) destinations in space: LEO, the cis-lunar region, the Moon and Mars.

Analysis of social media, recently introduced alongside the more traditional communication tools, shows that Astronauts and ISS catch the interest of users more than any other ESA space programme.

The presence of astronauts, i.e. of humans in space, makes it easier for people to relate and get more information on space activities and for this reason the inspirational value, in particular for young people, created by the ISS is very high and should not be underestimated. The advent of **social media** has introduced in the last decade a new way of communication and has provided people with a direct link to the astronauts on board the ISS. With respect to the more traditional communication tools (in-flight calls, appearances in public events and conferences), this has made it easier for people to relate to space activities, thus significantly increasing the interest surrounding manned spaceflight and, as a consequence, the interest in Science, Technology, Engineering, and Mathematics (STEM) activities related to it.

One of the analysis our team has made was assessing the number of views of the videos posted on ESA's YouTube webpage. The page collects all videos posted by ESA related to all typology of ESA missions, from human spaceflight to planetary exploration. We focused on the analysis of the "popular uploads", i.e. the absolute ranking of the most watched uploads, and the results for the ISS-related videos are quite outstanding.



Source: https://www.youtube.com/user/ESA

Figure 4 – Number of views on the 10 most viewed videos on ESA's YouTube page

As summarised in Figure 4 above, 6 of the 10 most popular upload posted by ESA are ISS related, with the remaining 4 distributed through other ESA missions.

Even if these numbers are not conclusive on the overall reach and inspirational value of ESA missions to the ISS, they give us a good understanding of astronauts' outreach, activities and, in general, of the level of attractiveness of human spaceflight activities.

34% of educational kits made by ESA for primary and secondary schools are inspired by Astronauts and ISS missions.

It is difficult to evaluate and quantify the impact of ISS based educational activities, especially on primary and secondary school students. An evaluation of the long-time effects of astronaut-related inspirational activities in primary and secondary schools for the UK is currently led by the UK Space Agency (activities around the mission of astronaut Tim Peake). Preliminary results are very positive (see related case study) but final results are not expected before the next 3 years.

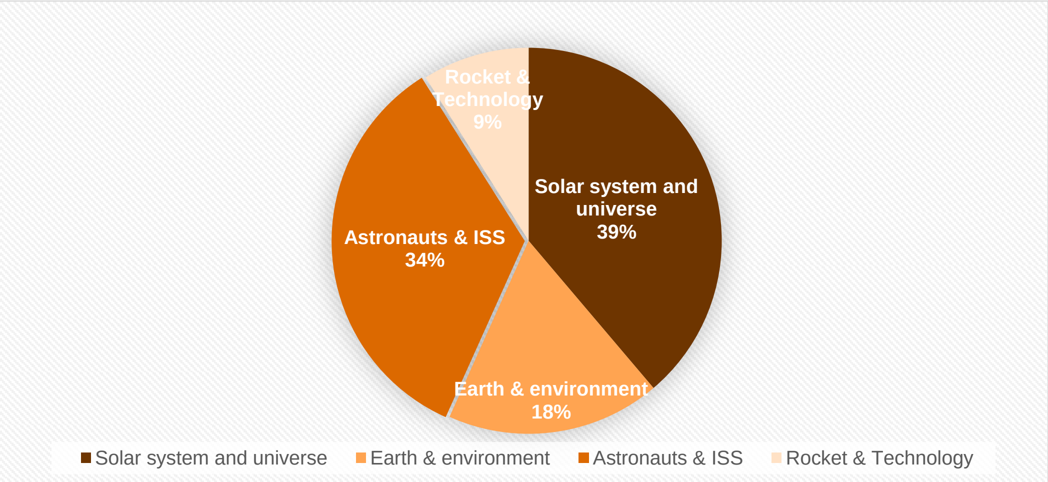


Figure 5 – Distribution of all educational kits made by ESA by theme

ESA has developed more than 60 different school kits based on all principal missions and programmes. As summarised in the figure above, 34% of the educational kits are based on Astronauts and ISS, i.e. the kits make use of human spaceflight example to introduce and explain a large number of scientific and technical topics to students. Human spaceflight together with Solar System and Universe observation missions contribute to more than 70% of the total number of educational kit, confirming the high inspirational level of the ISS programme.

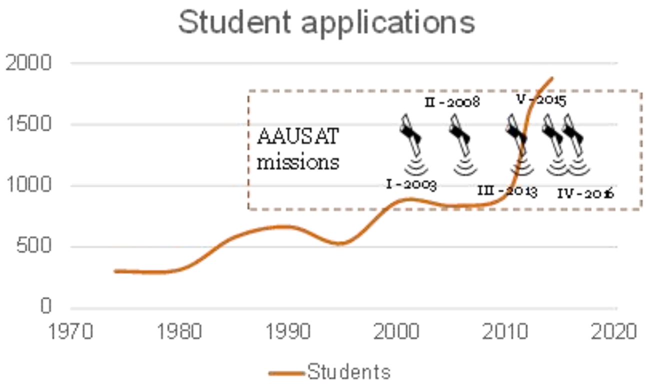
Tim Peake Primary Project (TPPP)

In 2015 ESERO UK initiated a project for Primary schools around the Tim Peake mission. More than 600 schools were involved in the project in the school year 2015/2016. The project has already produced a first set of results with more than 230 UK schools are assessing the impact after year 1 of the Tim Peake Primary Project (TPPP). Preliminary results show very positive impact of the TPPP and can be summarised as:

- 100% of schools report an increase in pupil engagement and enjoyment of science
- 99% of schools report an increase in pupil confidence in learning science and working scientifically
- 96% of schools report an increase in attendance – 30% to a great extent
- 99% of teachers reported that the TPPP quality was either very good (75%) or good (23%)
- 856 primary schools signed up for TPPP year 2. Around 650 of these schools have been allocated an ESERO UK Space Ambassador for face-to-face contact. The others will be offered an online course.

Recent possibilities of launching nanosats from the ISS have open new possibilities for university students.

ESA has recently offered the possibility to university students to develop nano-satellites to be launched from the ISS. This programme offers an interesting case study to showcase the inspirational value of the ISS and the value of astronaut support to universities. Next paragraph reports on the first European nano satellite made by students and launched from the ISS in October 2015.



"Mogensen effect" on the AAUSAT-5 satellite and the University of Aalborg

AAUSAT-5 is a small satellite designed and built by a team of students from Aalborg University in Denmark. Its main objective is to test student-built receivers for signals released by the Automated Identification System of sea vessels. The secondary objective is to test communication protocols designed by the students.

The AAUSAT-5 is the fifth nanosatellite built and launched by Aalborg University students, but is the first one launched from the ISS. Originally scheduled for launch during Danish astronaut Andreas Mogensen's mission on the ISS (IrISS mission, 2 to 9 September 2015), the satellite has been released from ISS in October 2016.

Andreas Mogensen supported the AAUSAT mission, exposing it to public in Denmark during his post mission public relation activities. This included an event dedicated to the AAUSAT-5 launch held at Aalborg University, plus additional visits made to the University and other PR events involving the student project team.

Because of the launch from the ISS and the astronaut support, the AAUSAT-5 mission registered the highest interest and public reach among all the AAUSAT missions. In addition, the University of Aalborg registered a steep increase in the number of application to the engineering courses following the mission and the related public relations events supported by the Danish astronaut.

Since 2001 the number of European experiments executed on the ISS has increased considerably going from an average of 27 experiments per year (period 2001-2007) up to 67 in the period 2008-2017.

The presence of the Columbus module, launched and integrated on the station in 2008, is considered the main driver of this 234% increase in the number of experiments. The Columbus module has hosted about 50% of the total number of the European experiments, while the US-Lab and the Russian segment have hosted respectively the 34% and 16% of the remaining experiments. As shown in the figure below, in the initial phase of the ISS utilisation the Russian segment hosted the majority of the European experiments. The launch of Columbus in 2008 marked a net change: in addition to the experiments executed in the European module, the post Columbus launch phase has seen the gradual reduction of the Russian-hosted experiments and a slight increase in the US-Lab hosted ones.

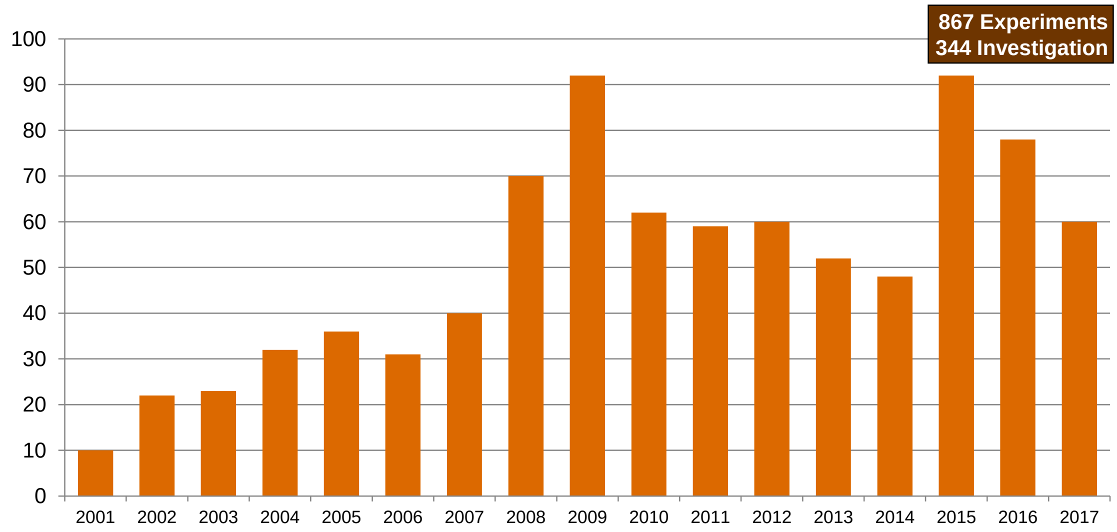


Figure 6 – Number of European-led experiments on the ISS

The international cooperation with Russia in the beginning of the utilisation phase enabled a learning process' on integration of experimentation modules and execution of experiments on the ISS. With the Columbus integration on the ISS, ESA has become an official partner of the USOS segment and has therefore strengthened the cooperation with NASA.

The majority of conducted experiments are implemented in life sciences (47%). The remaining 53% of investigation are almost evenly shared between technology demonstration (19% of total investigations), physical science (13%, further split in 10% of material science investigations and 3% of fluid physics), space science (11%, further split in 6% radiation physics activities and 5% of solar and plasma physics), and last but not least in 8% of educational activities. Oher disciplines, including Earth Observation, share the remaining 2%.

Most research activities have focused on fundamental research and basic principle observation. Therefore, tangible results in terms of applications and products are not immediately visible.

A smaller number of physical science research activities have been implemented through the MAP programme and have produced more tangible results along the TRL scale on the way to commercial applications and products.

The execution of the investigations on the ISS involved a large number of European researchers. About 338 different researchers have served as team coordinators for ESA experiments on the ISS, with an additional 1896 researchers involved in the different investigations.

These activities and teams generated relevant publications of high scientific value. Precise values of the number of publications could not be gathered, nevertheless a conservative estimation based on the European Science Foundation's independent analysis of the ELIPS programme sets the number of relevant publications in excess of 1000.

The involvement of European researchers in the ISS activities is distributed among all Member States which support ESA's Human Spaceflight optional programme. Distribution of team participants reflect the national contributions to the programme since 2001. Germany, France, Italy, Belgium and Sweden contributed for the 80% of the total national contribution to the ELIPS programme in the period 2001-2017. These countries together account for exactly the 80% of experiment coordinators in Europe and for the 73% of total number of participants.

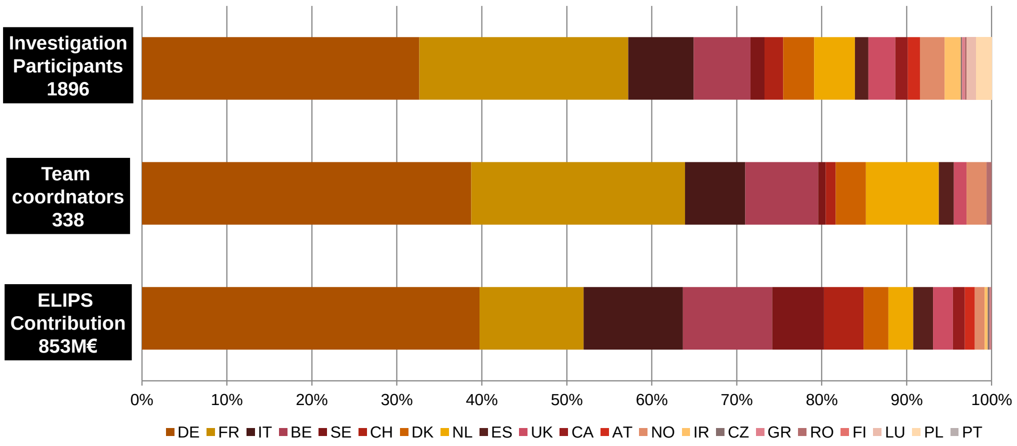


Figure 7 – Distribution of participants and team coordinators in Europe

When talking about the socio-economic benefits generated by the research activities on board of the ISS, we shall not reduce the discussion to the execution of experiments and the generation of scientific results, as this represents only a part of the created benefits.

Cooperation between different stakeholders has generated benefits along the entire value chain, including learning about best practices of space projects, and development and spin-off of innovative technologies. Many success stories supporting this finding have been identified and are reported in the study deliverables.

Research definition and experiment design

- Conception of research objectives
- Development of research protocol
- Design of research activities
- Definition of research requirements

Experimental facility design and space operation preparation

- Definition of system of and operational requirements
- Technology developments
- Research facility design, manufacturing and integration
- Operational products
- Astronaut training
- Launch campaign preparation

Research activity execution and data production

- Activity planning & verification
- Real-time support
- Data processing and distribution
- Data Analysis and scientific production
- Data preservation
- Post-flight data access

Best-practices **Technology** **Results**

Research definition and experiment design is where the stakeholders come together to define the strategic objectives of the research activities and characterise the experiment in terms of scientific and design requirements. These activities implied a high level of interaction between the scientific stakeholders, industrial stakeholders and the USOCS with the support of ESA and the National Space Agencies. The main benefit created in this phase can be summarised as the **creation of human capital and knowledge transfer.**

The second step of the ISS research value chain consists in the **design of the experimental facility** fulfilling the scientific and operational requirements defined in the research definition and experiment design step. The main benefit created in this phase can be summarised as the creation of new technologies and technology transfer. Design of experimental facilities and operation preparation for the ISS often implied creation of new technologies for miniaturisation of components, maximisation of reuse of resources such as power, water and oxygen, reduction of waste, and, most of all, application of the highest safety standards in order to protect astronaut's health. Many SME involved in the process have promptly capitalized on the experience, commercialising spin-off solutions that have been reused on Earth for commercial and humanitarian purposes.

Most of the technologies developed to serve the ISS programme have already found applications in other space projects, attracting new investments toward European space companies and therefore enabling additional revenues

The main example of this is the development of technologies for the welding of the external structure of Columbus and ATV, the Thermal Control System for the Columbus Module and the Service Module of the ATV. Mastering of these technologies has attracted about 1B€ for European industries under the NASA Multi-Purpose Crew Vehicle (MPCV) and Orbital Cygnus capsule. Both programmes serve the development of space transportation systems

Other technologies, developed and consolidated under the ISS programme, have generated spill-over applications in domains different from space. One example is the closed loop system used to optimize the utilisation of critical resources such as water and oxygen. Besides the potential utilisation in future exploration missions, these technologies find applications in submarine technology and in sustainable buildings.

The main future application of many technologies developed on the ISS is for deep space exploration missions. Preparation for future exploration missions and potential commercial utilisation of LEO also stimulated the development of technologies such as inflatable structures. Space technology development often involve SMEs spinning-in specific expertise and spinning-out new products and services.

Analysis of alternative scenarios indicates that the ISS programme has been efficient in terms of generation of GDP impact in Europe.

The alternative scenario analysis is structured in **four different scenarios** defined on the basis of an investment/asset model. The **investment/asset** model links the investment made by ESA to procure ISS elements (e.g. space and ground segment) and services (e.g. operational services, launch services) with the infrastructural (e.g. on-board active International Standard Payload Pack (ISPR) locations) and operational assets (e.g. hours of crew time, up- and download mass) created by the investment. The investment/asset model considers the implementation of **barter agreements** between ESA and the ISS international partners.

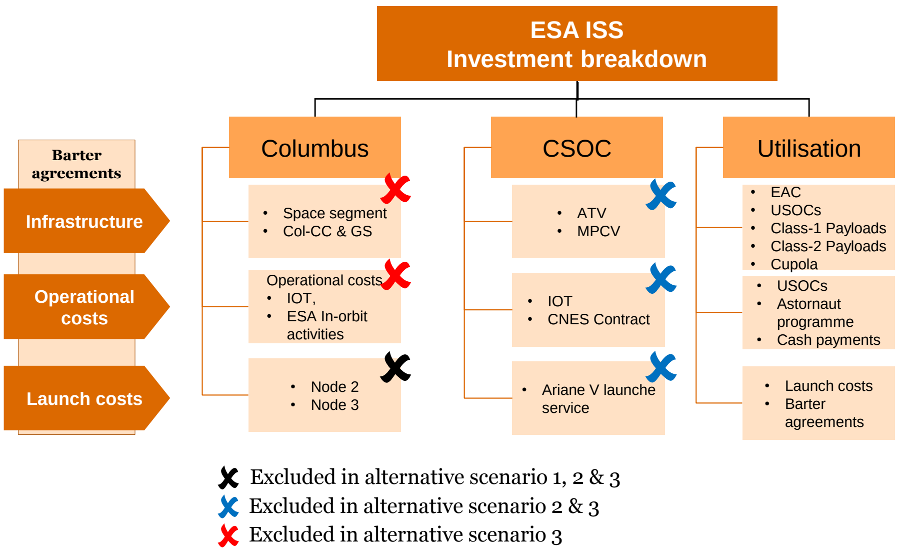


Figure 8 – Scenarios considered in the assessment

The **4 indicators** reported in the table below have been defined to characterize the baseline scenario and the alternative scenarios.

Indicator	**Description**	**Measurement unit**
No GDP impact	For the purpose of the scenario analysis the No GDP impact is calculated as the % of the scenario investment not generating a positive impact on ESA Member State GDP against the total cost of the scenario.	%
Cost of upload mass	Average cost of upload of 1 kg of utilisation mass. Indicator is calculated as the total utilisation mass uploaded in the scenario divided by the total of the cash payments.	€/Kg
Cost of astronaut time	Average cost of 1 hour of crew time utilisation. Indicator is calculated as the total utilisation crew time in the scenario, divided by the total of the cash payments.	€/Hours
Extra utilisation cost	Sum of all cash payments in the scenario necessary to cover the execution of the experiment on board the ISS when not covered by CSOC or barter agreements.	€

The table below shows all indicators for the four scenarios with the addition of the total scenario implementation costs in the bottom row. The total scenario implementation cost is the result of the sum of the ESA investments and the cash payments reported to 2015 values.

Indicator	**Baseline scenario**	**Alternative scenario 1**	**Alternative scenario 2**	**Alternative scenario 3**
No GDP impact	0%	6%	27%	28%
Cost of upload mass	0 €/Kg	71.073 €/Kg	238.000 €/Kg	94.514 €/Kg
Cost of astronaut time	0 €/Hours	377.823 €/Hours	1.265.196 €/Hours	665.361 €/Hours
Extra utilisation cost	0 €	0,5 B€	1,8 B€	1,0 B€
Total scenario implementation cost	9,2 B€	9,5 B€	6,9 B€	3,4 B€

While comparing the results, it appears that the baseline scenario is the second most expensive scenario with a total program cost of 9.2 B€, closely following alternative scenario 1 with a total cost of 9.5 B€. Alternative scenario 2 is the third most expensive scenario with 6.9 B€ and alternative scenario 3 is the cheapest one with a total expenditure of 3.4 B€.

Nevertheless, the baseline scenario proves to be the most efficient in term of generation of GDP impact in Europe. All other scenarios present a positive "No GDP impact" indicator with the alternative scenario 3 being the less favourable one despite being also being the less expensive one. Alternative scenario 1 is only slightly more expensive than the baseline scenario (+3.2%) but presents a much lower efficiency (6%) in the generation of positive impacts on ESA Member State GDPs.

This concept is summarised in the figure below showing the "No GDP impact" indicator on the top colour coded row, and the breakdown of the total scenario implementation costs in the staked bars diagram. Scenario costs are broken down in the cost of implementation of the Columbus programme, the nodes, the coverage of the CSOC, the utilisation costs and the cash payments. Cash payments are showed as negative numbers as they do not contribute to the creation of positive GDP in European Countries and therefore drive the value of the No GDP impact indicator.

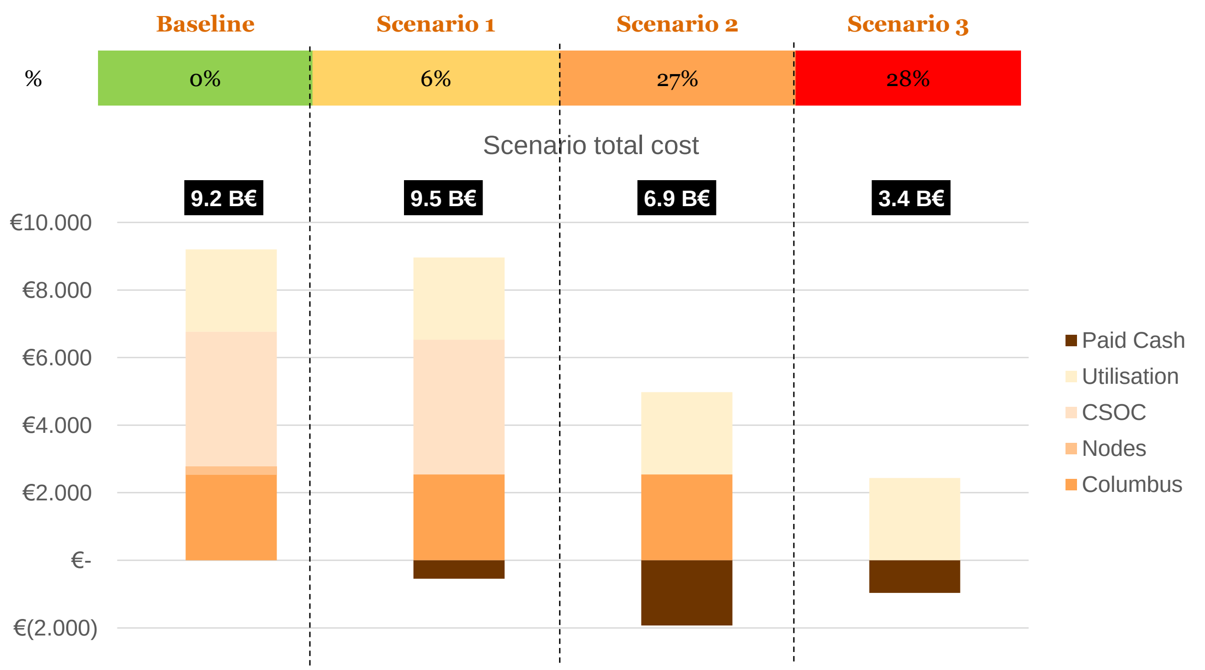


Figure 9 – Comparison of total scenario costs and production of GDP impact

The analysis of the ex-ante benefit has identified the three main lessons learned from the previous ISS phase.

The follow-up of the lessons learned and the implementation of measure to address them are expected to provide a relevant increase to the socio-economic benefit of the ISS between now and potentially 2024. These can be summarised as:

- The utilisation of large and complex experimental facilities is not the most efficient way to support research in microgravity.

- The implementation of commercial research activities has high potential and has not been exploited to its maximum extent so far.

- Scientific research has produced in many cases excellent data and allowed for important observations, nevertheless the level of re-utilisation of the produced data is very low and can be something to improve.

Expected benefits range from an increased production of higher quality scientific data, attraction of new European researchers toward microgravity science and research, increased commercialisation of new products and services (and therefore enabled revenues) stemming from commercialisation activities, and last but not least, an increase in the overall scientific production (e.g. publication, scientific papers) based on ISS generated data.