OECD Handbook on Measuring the Space Economy

OECD

2nd Edition

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BETTER POLICIES FOR BETTER LIVES

Please cite this publication as:
OECD (2022), *OECD Handbook on Measuring the Space Economy, 2nd Edition*, OECD Publishing, Paris, https://doi.org/10.1787/8bfef437-en.

ISBN 978-92-64-39938-9 (print)
ISBN 978-92-64-67115-7 (pdf)
ISBN 978-92-64-92348-5 (HTML)
ISBN 978-92-64-63209-7 (epub)

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Corrigenda to publications may be found on line at: www.oecd.org/about/publishing/corrigenda.htm.

Foreword

In 2012, the OECD published the *Handbook on Measuring the Space Economy*, the first international effort to systematically define and measure the "space economy", a challenging task given its array of very diverse economic activities. Since then, the definition of the space economy provided in the publication has been widely adopted by governments and the private sector alike.

Much has changed in the space economy over the past decade, not least due to the ever-growing number of countries and business enterprises involved in space activities. Despite the development of new and improved surveys in many parts of world and significant overall progress in the quality of publicly available economic data, the international comparability of space economy statistics remains limited. Therefore, the time seems ripe to provide a revision of the *Handbook on Measuring the Space Economy* to reflect the changing landscape of space activities, space technologies and user needs for metrics.

The objective of this second edition of the *Handbook* is to encourage and facilitate data collection among both incumbent and new actors involved in space activities, as well as to respond to the needs of the public agencies that still fund the bulk of space programmes and to private-sector decision makers who also stand to benefit from improved statistics on the space economy. It updates and expands upon the first edition of the *Handbook* in the following areas:

- **Revised concepts and definitions for the space economy:** High-level terms are defined with the aim to encourage improved international comparability for organisations wishing to compare their results.
- **Main principles of industry surveys:** Building on best international practices and an extensive review of more than 20 space industry questionnaires, key principles have been assessed and outlined for organisations interested in developing space economy surveys. Original pointers and lessons learnt are provided, which may give new ideas to long-standing developers of surveys.
- **A statistical companion introducing approaches to evaluating and assessing the impacts of space activities:** Step-by-step approaches to conducting evaluation and impact assessments are available from other sources and the *Handbook* does not attempt to replicate them. However, it explains different techniques that may be used and points to many existing studies focused on the impact of the space economy.

The *Handbook* is structured according to the following chapters:

- Chapter 1: Introducing the *OECD Handbook on Measuring the Space Economy*
- Chapter 2: Progress in concepts, definitions and measurement of the space economy
- Chapter 3: Monitoring the evolving cast of space actors
- Chapter 4: Using industry surveys to better understand the space economy
- Chapter 5: Strengthening assessment of the impacts of the space economy.

This publication is based on research and analytical work conducted by the OECD Space Forum Secretariat in the Science and Technology Policy Division, within the Directorate for Science, Technology and Innovation (STI). These activities are part of the broader programme of work of the OECD Committee for Scientific and Technological Policy (CSTP).

The indicators in this report are constructed using data regularly provided by member countries' authorities and from other OECD and international sources. The data primarily come from official sources such as OECD databases, statistical offices and national space agencies. In some cases, data are sourced directly from industry. The published indicators have been chosen based on reliability and timeliness of the required source data.

The team particularly thanks the member institutions of the OECD Space Forum for providing information, data and comments instrumental to the preparation of this publication. We also thank the representatives of industry, small businesses, academia, ministries and national delegates from the OECD Committee for Scientific and Technological Policy, who contributed substance during bilateral meetings and many OECD Space Forum workshops (see acknowledgements section).

The OECD Committee for Scientific and Technological Policy (CSTP) declassified the *OECD Handbook on Measuring the Space Economy, 2nd Edition* on 25 May 2022 by written procedure. The OECD Secretariat prepared it for publication.

Acknowledgements

This second edition of the *OECD Handbook on Measuring the Space Economy* is the result of many years of close co-operation between the OECD Secretariat, the ministries and space agencies represented in the OECD Space Forum, national statistical offices, private sector stakeholders, OECD colleagues and national delegates. We warmly thank all the experts who kindly contributed substance and comments in the course of the project.

The report was drafted by Claire Jolly, Marit Undseth, Mattia Olivari and James Jolliffe, from the OECD Space Forum in the Directorate for Science, Technology and Innovation (STI), with Barrie Stevens, senior advisor, kindly providing comments.

The OECD Space Forum Secretariat wishes to acknowledge with sincere thanks the support provided by the organisations forming the Steering Group of the OECD Space Forum: the Canadian Space Agency (CSA), Canada; the National Centre for Space Studies (CNES), France; the German Aerospace Centre (DLR), Germany; the Italian Space Agency (ASI), Italy; the Korea Aerospace Research Institute, Korea; the Netherlands Space Office, Netherlands; the Norwegian Space Agency and the Ministry of Trade, Industry and Fisheries, Norway; the Swiss Space Office, Switzerland; the UK Space Agency, United Kingdom; the Office of Technology, Policy and Strategy at the National Aeronautics and Space Administration (NASA), United States; and the European Space Agency (ESA).

The publication has greatly benefited from insights collected during OECD Space Forum workshops and seminars, with over 500 experts involved in substantive discussions in the past six years:

- Online seminars, held on 4 May and 8 June 2021, on "Space Economy Measurement and Surveys": The objective of these seminars was to understand the state-of-play in ongoing space economy surveys and related analysis from countries around the world.
- Online workshop, held on 9 October 2020, entitled "What's Next for the Space economy in the Era of Covid-19?" The workshop assembled agencies and space industry representatives to discuss recent evolutions in statistical indicators.
- Workshop, held on 2 October 2019 at OECD Headquarters in Paris, entitled "Linking Policies and Indicators: A Fresh Look": The main objectives of the workshop were to: 1) highlight new strategies in place at national and regional levels to attract and sustain space industry and investments; and 2) review the availability and quality of existing and experimental indicators used by public organisations to take stock of recent or ongoing programme evaluations and impact assessments.
- A meeting of the group of Space Agencies Technology Transfer Officers (SATTO), on 21 February 2019 at the International Space University (ISU) in Strasbourg, France: The objective was to discuss different national practices in technology transfers.
- Workshop, held on 27 April 2018 at OECD Headquarters, Paris, entitled "The Transformation of the Space Industry: Linking Innovation and Procurement": The objective was to review administrations' practices and their need for specific statistics.
- Workshop, jointly hosted by the OECD Space Forum and Space Agencies Technology Transfer Officers (SATTO), held on 21 June 2017 at the French space agency CNES, entitled "Technology

Transfer and Commercialisation (TTC) from Space Programmes: Enabling Conditions, Processes and Economic Impacts": The objective was to discuss measurement of space technology transfers.

- Workshop, held on 22-23 June 2017 at OECD Headquarters, Paris, on "Economic and Innovation Indicators for the Space Sector": The main objective was to take stock of recent public efforts to collect and analyse data and indicators related to economic development and innovation in the space sector, sharing experiences with stakeholders from OECD countries and beyond, including industry associations.
- Workshop, held on 10-11 March 2016, at OECD Headquarters, Paris, entitled "Data to Decisions: Valuing the Societal Benefit of Geospatial Information". The event was hosted by OECD and organised in collaboration with NASA, USGS and the GEOValue Community: It was the first technical workshop assembling so many economists and scholars from academia and research institutes to specifically discuss the value of geospatial information and satellite data. The workshop brought together around 100 participants from 22 countries (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ghana, Japan, Korea, Mexico, Netherlands, Nigeria, Norway, South Africa, Sweden, Switzerland, Uganda, United Kingdom, United States, Viet Nam). (See Chapter 5 on impacts.)
- Workshop, held on 25 May 2015, at OECD Headquarters, Paris, entitled "Taxonomy in the Space Economy: Defining, Describing and Classifying Actors engaged in Space Activities": The main objectives of the workshop were to share practical information about taxonomies and data collection to support national policies and agencies' priorities and to build consensus on basic definitions and perimeters for space-related activities to improve international comparability.

Special thanks go to Hendrik Fischer and Mara Grunewald from the DLR and David Haight, Aaron Parsons and James Jarvis-Thiébault from the CSA, who contributed original material for the *Handbook* based on Canadian and German experiences in space industry surveys (see Annex 4.B). Further special thanks go to Tina Highfill at the Bureau of Economic Analysis in the US Department of Commerce, as well as Pierre Lionnet at the Eurospace industry association, who kindly provided valuable inputs during the drafting of this publication.

Finally, we thank colleagues from the OECD Directorate for Science, Technology and Innovation for their careful review and comments, notably Alessandra Colecchia, Head of the Science and Technology Policy Division, and Fernando Galindo-Ruedo, senior economist, coordinator of the activities of the OECD Working Party of National Experts on Science and Technology Indicators (NESTI).

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Abbreviations and acronyms

ADR	Active debris removal
AAAAI	Australian Association of Aviation and Aerospace Industries
AIA	Aerospace Industries Association
AIAB	Aerospace Industries Association of Brazil
	Associação das Indústrias Aeroespaciais do Brasil
AIAC	Aerospace Industries Association of Canada
AIAD	Federation of Italian Companies for Aerospace, Defence and Security (Italy)
	Associazione delle Industrie per l'Aerospazio i Sistemi e la Difesa
ANZSIC	New Zealand Standard Industrial Classification
ARTES	Advanced Research in Telecommunications Systems
ASD	Aerospace and Defence Industries Association
ASI	Italian Space Agency (Italy)
	Agenzia Spaziale Italiana
ASJC	All Science Journal Classification
BDLI	German Aerospace Industries Association (Germany)
	Bundesverband der Deutschen Luft- und Raumfahrtindustrie
BEA	Bureau of Economic Analysis (United States)
BELSPO	Belgian Science Policy Office (Belgium)
BIC	Business incubation centre
CAD	Canadian dollar (currency)
CBA	Cost benefit analysis
CEA	Cost effectiveness analysis
CGE	Computable general equilibrium model
CHF	Swiss franc (currency)
CIP	Classification of Instructional Programmes (United States)
CNES	National Centre for Space Studies (France)
	Centre National d'Études Spatiales

CPA	Classification of Products by Activity
CPC	Central Product Classification
CPF	Classification of products (France)
	Classification des produits française
CSA	Canadian Space Agency (Canada)
DALY	Disability-adjusted life year
DARPA	Defense Advanced Research Projects Agency (United States)
DLR	German Aerospace Center
	Deutsches Zentrum für Luft-und Raumfahrt
DTH	Direct-to-home satellite services
EARSC	European Association of Remote Sensing Companies
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
EGNOS	European Geostationary Navigation Overlay Service
EISCAT	European Incoherent Scatter Scientific Association
EO	Earth observation
ESA	European Space Agency
ESO	European Southern Observatory
ESOC	European Space Operations Centre
ESTEC	European Space Research and Technology Centre
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUR	Euro (currency)
FAA	Federal Aviation Administration (United States)
FCT	Foundation for Science and Technology (Portugal)
	Fundação para a Ciência e Tecnologia
FORD	Fields of Research and Development for the higher education sector
FP7	European Union’s Seventh Research Framework Programme
FTE	Full-time equivalent
GBARD	Government Budget Allocations for Research and Development
GBP	British pound sterling (currency)
GDP	Gross domestic product
GERD	Gross domestic R&D expenditure
GIFAS	French Aerospace Industries Association (France)
	Groupement des Industries Françaises Aéronautiques et Spatiales

GIS	Geographic information system
GNSS	Global navigation satellite system
GPS	Global Positioning System
GSA	European GNSS Agency
HECoS	Higher Education Classification of Subjects (United Kingdom)
HEIs	Higher education institutions
HS	Harmonised system
IADC	Inter-Agency Space Debris Coordination Committee
IAEA	International Atomic Energy Agency
ICT	Information and communication technology
ILO	International Labour Office
IMPLAN	Impact analysis for planning
INSEE	National Institute for Statistics and Economic Studies (France)
	Institut National de la Statistique et des Études Économiques
INTA	National Institute of Aerospace Technology (Spain)
	Instituto Nacional de Técnica Aeroespacial
IO	Input-output
IOA	Input-output analysis
IP	Intellectual property
IPR	Intellectual property rights
ISCED	International Standard Classification of Education
ISCO	International Standard Classification of Occupations
ISECG	International Space Exploration Coordination Group
ISED	Innovation, Science and Economic Development Canada
ISIC	International Standard Industrial Classification
ISON	International Scientific Optical Network
ISRO	Indian Space Research Organisation (India)
ISU	International Space University
ITCS	International Trade in Commodity Statistics database
ITU	International Telecommunications Union
JAXA	Japan Aerospace Exploration Agency (Japan)
JPL	Jet Propulsion Laboratory
JWST	James Webb Space Telescope
KARI	Korea Aerospace Research Institute (Korea)
KRW	Korean won (currency)

LEO	Low-earth orbit
NACE	Statistical Classification of Economic Activities in the European Community
NAF	Classification of Activities (France)
	Nomenclature d'activités française
NAICS	North American Industry Classification System
NASA	National Aeronautics and Space Administration (United States)
NOAA	North American Industry Classification System
NOSA	Norwegian Space Agency (Norway)
NSO	Netherlands Space Office (Netherlands)
NSTP	UK National Space Technology Programme
OECD	Organisation for Economic Co-operation and Development
ONERA	The French Aerospace Lab (France)
	Office National d'Études et de Recherches Aérospatiales
OOS	On-orbit servicing
PNT	Positioning, navigation and timing
PPP	Purchasing power parities
PT Space	Portugal Space
PRODCOM	“Community Production” (European statistics on the production of manufactured goods)
QUALY	Quality-adjusted life year
R&D	Research and development
RIMS-II	Regional Input-Output Modelling System
Roscosmos	Russian Federal Space Agency (Russian Federation)
SANSA	South African Space Agency (South Africa)
SATTO	Space Agencies Technology Transfer Officers group
SBIR	Small Business Innovation Research
SESA	Space Economy Satellite Account (United States)
SIA	Satellite Industry Association
SIAA	Space Industry Association of Australia
SIATI	Society of Indian Aerospace Technologies and Industries
SITC	Standard International Trade Classification
SJAC	Society of Japanese Aerospace Companies (Japan)
SME	Small and medium-sized enterprises
SNA	System of National Accounts
SNSA	Swedish National Space Agency (Sweden)
SSO	Swiss Space Office (Switzerland)

STEM	Science, technology, engineering and mathematics
STTR	Small Business Technology Transfer
TTC	Technological transfer and commercialisation
TTO	Technology transfer offices
UKSA	United Kingdom Space Agency
UNECE	United Nations Economic Commission for Europe
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNOOSA	United Nations Office of Outer Space Affairs
USD	US dollar (currency)
USGS	United States Geological Survey
VOI	Value of information
VSAT	Very small aperture terminal
WMO	World Meteorological Organization

Executive summary

Why a new *Handbook on Measuring the Space Economy*?

Space activities are growing globally, and the services derived from them are increasingly important to society. This second edition of the *Handbook on Measuring the Space Economy* responds to the needs of policymakers from multiple economic sectors that are reflecting on such changes in their measurement strategies. It takes account of the evolving landscape of space activities, technologies and user needs surrounding two core observations:

- **Increasingly, a wide diversity of actors is involved in space activities:** Government actors more than ever pursue strategic objectives in the space economy in tandem with commercial actors. A better tracking of the effects of public and private expenditure in the space economy is required if the overall impact of such trends is to be assessed.
- **Studying the economics of space activities has become professionalised but measuring the space economy remains a challenge:** The range of space activities has evolved significantly over the past ten years. Critical infrastructures such as telecommunications and an increasing number of commercial digital applications now depend heavily on space capabilities. In advanced economies, the space economy is becoming more complex and the line between space and non-space activities is increasingly difficult to assess.

Key space economy measurement challenges

Important efforts are underway to better understand the space economy and common practices are beginning to emerge. Increasing numbers of space economy surveys, for example, mean that the quality and coverage of publicly available data and analysis are improving. However, key measurement challenges remain.

Existing statistical classification systems do not define space activities in isolation from other related activities. And no technical guidelines exist to ensure statistics are comparable over time and across sectors and countries. The information required to conduct space economy evaluations is therefore not readily available and often gathered on a case-by-case basis (information is particularly scarce concerning the non-market effects of space activities).

Meanwhile, collecting information on the space economy through special surveys can be a costly and time-consuming exercise. As a result, space economy assessments tend to be heavily reliant on case studies and expert opinion, which can make it difficult to test them for validity and compare with other areas. In impact assessment, robust counterfactuals are not always developed, which increases the risk of inaccurate estimations.

Solutions to the challenges of measuring the space economy are provided in this *Handbook*

This publication updates and expands upon the first edition of the *Handbook* with a particular focus on resolving measurement challenges. It provides:

- **Revised definitions of space economy terms and concepts:** A high-level definition of the space economy is given to set the boundaries of assessments and updated industrial classification codes are provided to encourage international comparability.
- **Principles for conducting space economy surveys:** Based on internationally agreed standards and an extensive review of more than 20 space industry questionnaires, the key principles for developing space economy surveys are provided alongside advice on their implementation.
- **An introduction to space activity impact assessment:** Existing studies on the impacts of the space economy are summarised and the techniques used are outlined to introduce readers to the methods currently employed.

Recommendations for improving evaluations of the space economy

Given the challenges outlined above, studies based on the results of targeted surveys will likely remain the most efficient approach for space economy analysis in the near future. But space administrations and statistical agencies are encouraged to be innovative in their use of different data sources including through the exploration of national accounting approaches to space economy measurement. In particular, the *Handbook* recommends practitioners to:

- **Develop policy-oriented evaluation frameworks and support data collection:** Ultimately, space economy evaluations should provide the evidence used to support policy objectives. A policy focus should provide clarity on what to measure, justify adequate resources devoted to data collection and ensure results inform decisions.
- **Make better use of official statistics:** Although space activities tend not to be readily visible in official statistics, official data from structural business and other national surveys can contain useful information when supplemented with more granular data from space industry surveys, annual reports, and, when available, grants and contract data.
- **Rely upon internationally recognised definitions and practices when conducting surveys:** The government organisations and industry associations conducting industry surveys outlined in this *Handbook* can improve the coherence of their results through the adoption of internationally agreed definitions and methodologies. Using standards can also reduce the resource burden of conducting surveys in smaller organisations.
- **Collaborate with knowledgeable organisations:** Partnerships between space agencies, national statistical offices and industry associations can facilitate methodological support, add credibility to results and, in some cases, help to secure extra funding. Collaboration may also result in greater outreach and wider visibility of the evidence produced.
- **Document evaluation methodologies and make them publicly available:** Ensuring that methodological choices are clearly documented and available as widely as possible should enable reproducibility and improve confidence in the results. In general, transparency can facilitate improvements in evaluation design and encourage stakeholder engagement in evidence building.
- **Strengthen international co-operation and co-ordination:** The OECD Space Forum will continue working with governments, national statistical offices, industry, academia and the broader space community to improve space economy measurement and provide the evidence required to make effective decisions on the space economy.

1 Introducing the *OECD Handbook on Measuring the Space Economy*

This chapter introduces the *OECD Handbook on Measuring the Space Economy*. It describes the background, outlines the objectives and the target audience for the report and explains changes introduced since the first edition of the *Handbook*.

What is the *OECD Handbook on Measuring the Space Economy*?

In 2012, the OECD published its *Handbook on Measuring the Space Economy*. It resulted from the work of the OECD Space Forum and benefited from extensive consultation in the space community and beyond. The *Handbook* represented the first international effort to systematically define and measure the "space economy" and its constituent economic activities (OECD, 2012[1]). Since then, the definition of the space economy provided in the publication has been extensively adopted by governments and the private sector alike.

Much has changed in the space economy over the past decade, with an ever-growing number of countries and business enterprises involved in space activities. Despite the development of new and improved surveys in many parts of the world and overall progress in the quality of publicly available data, the international comparability of space economy statistics remains limited. It is therefore time to provide a revision of the *OECD Handbook on Measuring the Space Economy (*the *Handbook* herein*)* to reflect the changing landscape of space activities, space technologies and subsequent evolving user needs.

The objectives of this second edition of the *Handbook* are to encourage and facilitate data collection among both incumbent and new actors involved in space activities, respond to the needs of the public agencies that still fund the bulk of space programmes and provide an introduction to industry and private decision makers who will also benefit from improved statistics on the space economy.

This revised version aims to share the lessons learnt from the government sector and business enterprises in measuring the space economy and help stakeholders develop adequate measurement strategies to support their evidence-based decision-making. It builds on key concepts, definitions, and practices, which can be found in international guidelines such as the *Frascati* and *Oslo Manuals*. Readers are encouraged to review and adopt the international guidelines in their statistical practices (OECD, 2015[2]; OECD/Eurostat, 2018[3]).

Against this backdrop, the *Handbook* provides a set of Chapters that illustrate how an analyst might:

- use pragmatically the recent progress in concepts, definitions and measurement of the space economy (Chapter 2)
- follow the evolving cast of space actors for measurement purposes (Chapter 3)
- track the performance and evolutions of the space economy with industry surveys and their indicators (Chapter 4)
- and compare the effects of space activities over time, and as compared to other economic activities (Chapters 5).

Measuring the space economy will remain an evolving field as commercial space activities, in particular, are changing fast. Further revisions of the *Handbook* are therefore likely to be required as the space economy changes and new statistical practices are adopted.

As with all statistical companions published by the OECD, the audience for this *Handbook* includes a broad range of users. They are likely to include:

- policymakers and representatives of government agencies that form a major part of the demand for more detailed information on the space economy
- commercial actors active in the space community and beyond, many of whom have contributed data and analysis for this *Handbook*
- researchers in different disciplines and analysts who interpret statistical information and need to access the methodologies that underlie that information
- and, finally, international organisations whose information requirements centre on comparability across countries.

Why and how was the *Handbook* revised?

The OECD Space Forum is a group of space agencies and ministries from ten countries (at time of writing) and the European Space Agency. Together, they contribute to improving knowledge of the economics of space activities to support evidence-based policies nationally and internationally. The pervasiveness of space applications in many daily activities is growing and there are an increasing number of commercial space activities. The Forum therefore decided in 2012 that definitions of the space economy should not be limited to a few characteristics only (i.e. space launchers and satellites).

A comprehensive view of the space economy was supported by experts in several workshops and during broad consultations with diverse administrations, industry associations, as well as small and large stakeholders in the private sector. Using lessons learnt from other sectors, a definition of the space economy that encompasses the many dimensions of programmes, services and actors was established. The following working definition formed the starting point for the first *Handbook on Measuring the Space Economy* (OECD, 2012[1]).

> *The space economy is the full range of activities and the use of resources that create and provide value and benefits to human beings in the course of exploring, understanding, managing and utilising space.*
>
> *Hence, it includes all public and private actors involved in developing, providing and using space-related products and services, ranging from research and development, the manufacture and use of space infrastructure (ground stations, launch vehicles and satellites) to space-enabled applications (navigation equipment, satellite phones, meteorological services, etc.) and the scientific knowledge generated by such activities. It follows that the space economy goes well beyond the space sector itself, since it also comprises the increasingly pervasive and continually changing impacts (both quantitative and qualitative) of space-derived products, services and knowledge on economy and society (OECD, 2012[1]).*

This definition has been used extensively by the space community and public bodies, albeit with some differing interpretations on which activities to include in specific segments of the space economy.

New challenges in terms of measurement and delineation

Since the publication of the first edition of the *Handbook*, the landscape of space activities has undergone significant changes (see for instance OECD (2014[4]; 2019[5]; 2020[6]; 2021[7])) with new important challenges for measuring the space economy.

The sector has undergone structural changes, as the lowered cost of access to space places higher emphasis on digital assets. Business enterprise activities increasingly span across entire sections of the space economy value chain. Many space start-ups engage in both manufacturing and data exploitation. Large space-manufacturing incumbents are moving further down the value-chain to reach final customers outside of the traditional government sector.

As the digitalisation of the economy increases apace, the exploitation of satellite data and signals is playing an increasingly important role in the generation of societal value. However, the lines between space and non-space activities are becoming more blurred. New data economy actors and activities are entering the space economy and satellite data are increasingly used alongside other data sources in the “mainstream” economy. This makes it difficult to attribute the value generated through certain activities to the space economy.

Finally, the announcement and early deployment of mega-constellations for satellite broadband in the low-earth orbit and the involvement of several major information and communication technology enterprises in the sector has created significant optimism on market prospects. Space activities are attracting more interest from public and private investors.

Table 1.1 contains estimates of the size of the space economy taken from various recent publications. According to some financial estimates, the space economy may surpass USD 1 trillion by 2040 (Morgan Stanley, 2020[8]). In comparison, a more conservative study conducted by the US Institute of Defense Analyses estimated the size of the space economy in 2016 at USD 167 billion, suggesting that the space economy should be measured in terms of value added, not revenues (Crane et al., 2020[9]).

The great discrepancy in estimates is therefore largely due to the use of different definitions and delimitations of the space economy. In particular, the inclusion or exclusion of services supporting consumer markets such as direct-to-home television, and consumer applications relying on global navigation satellite systems (GNSS) signals. Many of the consumer products used to access satellite capacities (e.g. satellite dishes, set-top boxes) often included in estimates, may actually be imports from third countries with limited space investments. In addition, different methodologies are used to estimate the value of space products and services, measuring either output (i.e. revenue) or value added (i.e. output minus intermediate inputs), and in most cases double-counting government-funded space activities, thus not making obvious to the readers what is actually included in the estimates.

Table 1.1. Recent estimates of the space economy

Organisation	Current estimates (2016)	Forecasts (2040)	General comments	Activities and sector(s) included in space economy estimates
Satellite Industry Association	USD 339.1 billion	n.a.	Space economy estimate includes both government budgets and commercial revenues, which may inflate the final estimate, as commercial actors have many government customers	Government budgets, satellite services (telecommunications and remote sensing), ground equipment (network equipment and consumer equipment), satellite manufacturing, launch industry, commercial human spaceflight
Morgan Stanley	USD 350 billion	USD 1.1 trillion	Based on SIA data, with forecast based on 5% compound annual growth rate, driven by internet and consumer broadband	
Merrill Lynch/Bank of America		USD 2.7 trillion	Similar starting definition as SIA and Morgan Stanley, with growth forecast based on 7% compound annual growth rate, highlighting the "cis-lunar" economy, e.g. Internet, on-orbit services and resource extraction	
Space Foundation	USD 329.3 billion	n.a.	Same potential issue of double-counting as the SIA estimate	Government space budgets, commercial space products and services, commercial infrastructure and support industries
Institute for Defense Analyses	USD 166.8 billion	n.a.	Measures value added, not revenues	Government budgets, revenues from satellite services and space service user support

Note: n.a.=Not available.
Sources: OECD (2019[5]), *The Space Economy in Figures*, https://dx.doi.org/10.1787/c5996201-en and Crane et al. (2020[9]), "Measuring the space economy: Estimating the value of economic activities in and for space", www.ida.org/-/media/feature/publications/m/me/measuring-the-space-economy-estimating-the-value-of-economic-activities-in-and-for-space/d-10814.ashx.

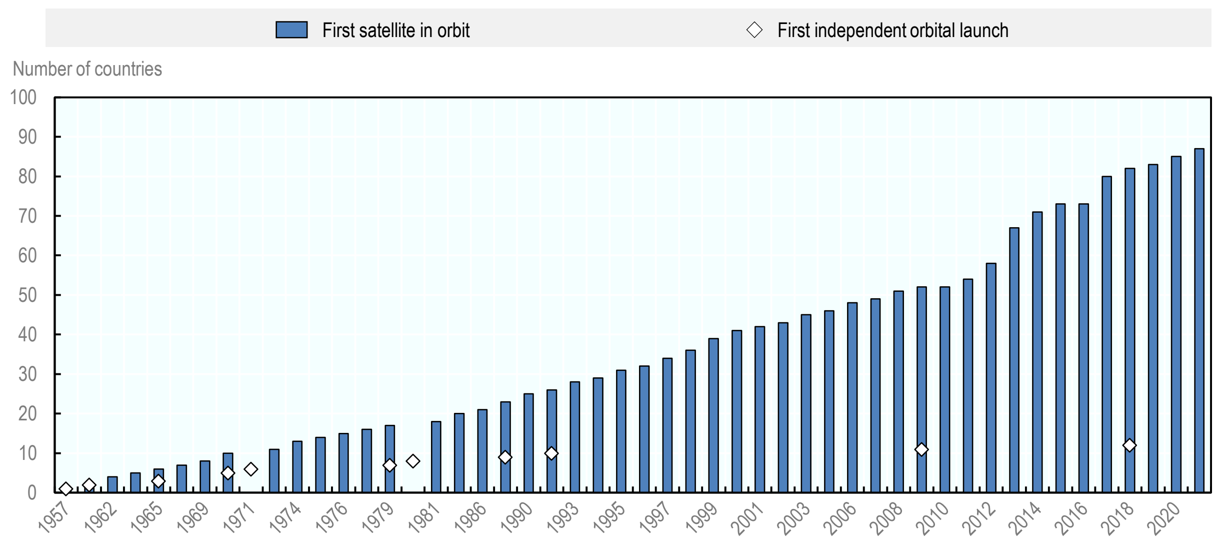
Statisticians and economists must therefore grapple with the question of where to draw the line between space and non-space activities. Should mobility services relying on GNSS signals be included in the space economy? What about business enterprises using satellite imagery along with multiple other non-space related types and data in their analysis?

More government space actors and a growing body of evidence

More government actors pursuing different objectives are engaged in space activities than ever before. Since the launch of Sputnik in 1957, more than 80 countries have registered a satellite in orbit. The rate at which new countries are launching satellites to orbit has increased over the last decade (Figure 1.1). Since the early 2000s, more than 30 new space agencies or offices have been established on all six continents and in both high and lower-income economies (ESPI, 2020[10]).

Figure 1.1. Almost 80 countries have registered a satellite in orbit

Number of countries having registered a satellite in orbit and/or launched a rocket successfully



Source: Updated from OECD (2019[5]), *The Space Economy in Figures*, https://dx.doi.org/10.1787/c5996201-en.

In parallel, studying the economics of space activities has become increasingly professionalised. A number of space administrations now employ specialist teams of economists and other analytical professions (e.g. Canadian Space Agency (CSA), National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), UK Space Agency (UKSA), the French space agency (CNES), Korea Aerospace Research Institute (KARI), Italian Space Agency (ASI)) and/or are dedicating resources to data collection through surveys. Increasingly, partnerships are being built with national statistical offices (OECD, 2020[11]). In the same vein, the European Space Agency (ESA) has created a dedicated Space Economy unit. The ESA unit works to improve economic measurement and collect and share best practices in socio-economic impact assessment in co-operation with the OECD Space Forum, ESA member states and relevant government entities involved in economic analysis and statistics (European Space Agency, 2021[12]).

The need to better track the implementation and impacts of public expenditure in the space economy is increasing in most countries. Contributing to economic growth and societal wellbeing are now key objectives of most government space strategies. This needs to be better reflected in data and indicators. In addition, the number of industry associations and consulting firms involved in providing market studies has also grown. This trend is providing novel data but also sometimes-conflicting information on the space economy.

Some well-established datasets on space activities now go back to the early 1990s (e.g. Eurospace industry association survey, the CSA's State of the Canadian Space Sector survey), while several new surveys and studies have been carried out in recent years. These include those conducted alongside national statistical offices to allow comparisons with other sectors of the economy as well as enriched analysis from the breadth of data these statistical agencies have. The US Space Economy Satellite Account (Highfill, Jouard and Franks, 2020[13]), for example, is the first satellite account of its kind and is inspiring others internationally.

Other efforts include the most recent German Space Agency (DLR) industry survey, Australia's economic snapshot of its space industry (Australian Space Agency, 2021[14]), the launch of the French space agency's Observatory of the Space Economy (CNES, 2021[15]), the first United Arab Emirates space industry survey, a major Italian cost-benefit analysis analysing the impacts of public policies in the space sector (Università di Milano and Agenzia Spaziale Italiana, 2021[16]), the measurement of Denmark's space economy (London Economics and Rambøll Management Consulting, 2016[17]), and the methodological advances for valuing satellite earth observation data in our economies (GeoValue, 2021[18]; Valuables Consortium, 2021[19]).

Despite these many developments, data comparability across time, economic sectors and countries remains a challenge. This makes it difficult to compare assessments with each other and, ultimately, to evaluate confidently the value generated from public expenditure in the space economy.

Within this context, the OECD Secretariat launched a consultation process concerning the evolving definition of the space economy and the activities that take place within it. More than 100 organisations from national administrations, industry and professional associations were consulted. There was a broad consensus about standardising the overarching concept of the "space economy" in order to promote a common understanding and a common vocabulary. A standard definition may prove especially useful when distinguishing between different space activities and trying to assess the health and socio-economic impact of the space economy overall.

This *Handbook* recommends an approach to measurement that is as comprehensive as possible in order to provide the best available evidence to policymakers and decision makers in the space economy.

Process for revision

The new *Handbook* is the result of extensive OECD research activities on the economics of space activities conducted over the past six years with strong involvement from members of the OECD Space Forum. The process involved multilateral and bilateral consultations with experts from space agencies, public research centres, national statistical offices, intergovernmental organisations, academia and industry (from very small to large business enterprises). The research also benefited from insights collected during many technical seminars and workshops, each assembling between 30 and 120 participants, with more than 40 countries represented during the process. To illustrate:

- Online seminars, held on 4 May and 8 June 2021, on "Space Economy Measurement and Surveys": The objective of these seminars was to understand the state-of-play in ongoing space economy surveys and related analysis from countries around the world.
- Workshop, held on 9 October 2020, entitled "What's next for the Space Economy in the Era of Covid-19?" The workshop assembled agencies and space industry representatives discussing recent evolutions in statistical indicators.
- Workshop, held on 2 October 2019 at OECD Headquarters in Paris, entitled "Linking Policies and Indicators: A Fresh Look": The main objectives of the workshop were to: 1) highlight new strategies in place at national and regional levels to attract and sustain space industry and investments; and 2) review the availability and quality of existing and experimental indicators used by public organisations to take stock of recent or ongoing programme evaluations and impact assessments.
- A meeting of the group of Space Agencies Technology Transfer Officers, on 21 February 2019 at the International Space University in Strasbourg, France, entitled "Meeting on Technology Transfers from Space".

- Workshop, held on 27 April 2018 at OECD Headquarters, Paris, entitled “The Transformation of the Space Industry: Linking Innovation and Procurement”: The objective was to review administrations’ practices and their need for specific statistics.
- Workshop, jointly hosted by the OECD Space Forum and Space Agencies Technology Transfer Officers (SATTO), held on 21 June 2017 at the French space agency CNES, entitled “Technology Transfer and Commercialisation from Space Programmes: Enabling Conditions, Processes and Economic Impacts”.
- Workshop, held on 22-23 June 2017 at OECD Headquarters, Paris, on “Economic and Innovation Indicators for the Space Sector”: The main objective was to take stock of recent public efforts to collect and analyse data and indicators related to economic development and innovation in the space sector, sharing experiences with stakeholders from OECD countries and beyond, including industry associations.
- Workshop, held in Paris on 10-11 March 2016, at OECD Headquarters, Paris, entitled “Data to Decisions: Valuing the Societal Benefit of Geospatial Information”: The event was hosted by OECD and organised in collaboration with NASA, USGS and the GEOValue Community. It was the first technical workshop assembling so many economists and scholars from academia and research institutes to specifically discuss the value of geospatial information and satellite data. The workshop brought together around 100 participants from 22 countries (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ghana, Japan, Korea, Mexico, Netherlands, Nigeria, Norway, South Africa, Sweden, Switzerland, Uganda, United Kingdom, United States, and Viet Nam). (See Chapter 5 on impacts.)
- Workshop, held on 25 May 2015 at OECD Headquarters, Paris, entitled “Taxonomy in the Space Economy: Defining, Describing and Classifying Actors Engaged in Space Activities”: The main objectives of the workshop were to share practical information about taxonomies and data collection to support national policies and agencies’ priorities and to build consensus on basic definitions and perimeters for space-related activities to improve international comparability.

A non-exhaustive list of practitioners and experts who kindly contributed substance and comments from space agencies, ministries, and industry in the course of the project is provided in the acknowledgements at the beginning of the *Handbook*.

What are the main differences between this and the first edition of the *Handbook*?

The new *Handbook* updates and expands upon the first edition of the *Handbook* in the following broad areas:

- **Revised concepts and definitions for the space economy:** The aim is to clarify high-level definitions for practitioners and to encourage improved international comparability for organisations wishing to compare their results.
- **Main principles of industry surveys:** Building on best international practices (*Frascati* and *Oslo Manuals*) and an extensive review of more than 20 space industry questionnaires, key principles and practical advice are provided for organisations interested in developing space economy surveys. Original pointers and lessons learnt are provided, which may give new ideas to long-standing developers of surveys.
- **A statistical companion introducing a diversity of evaluation and impact assessments of space activities:** The *Handbook* does not provide a step-by-step approach in conducting evaluation and impacts assessments (there are existing resources that do not need to be

duplicated). However, it points to many existing studies of the impact of the space economy and explains different techniques that may be used.

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2 Progress in concepts, definitions and measurement of the space economy

This chapter of the *Handbook* outlines key concepts and defines the space economy and other key terms used to describe and measure activities in the space economy. It also identifies different space products and services in national and international statistical frameworks to facilitate measurement.

Defining the "space economy"

Space applications are increasingly pervasive in many daily activities and there are a growing number of commercial activities taking place in orbit.

A decade ago, the OECD Space Forum conducted a series of expert workshops and broad consultations with diverse administrations, industry associations and small and large private sector stakeholders, in order to develop a concept of the space economy that captured the full range of space activities. Using lessons learnt from other sectors, notably the digital economy, a definition of the space economy was developed with the aim to encompass the different dimensions of programmes, services, and actors. The following working definition formed the starting point for the first *Handbook on Measuring the Space Economy* published in 2012 (OECD, 2012[1]).

> *The space economy is the full range of activities and the use of resources that create and provide value and benefits to human beings in the course of exploring, understanding, managing and utilising space.*
>
> *Hence, it includes all public and private actors involved in developing, providing and using space-related products and services, ranging from research and development, the manufacture and use of space infrastructure (ground stations, launch vehicles and satellites) to space-enabled applications (navigation equipment, satellite phones, meteorological services, etc.) and the scientific knowledge generated by such activities. It follows that the space economy goes well beyond the space sector itself, since it also comprises the increasingly pervasive and continually changing impacts (both quantitative and qualitative) of space-derived products, services and knowledge on economy and society (OECD, 2012[1]).*

Ever since, this OECD definition has been used extensively by the space community and public bodies, albeit with differing interpretations of which activities to include in specific segments.

Over the years, one prominent issue in measurement has concerned the inclusion of many new, mainly digital, goods and services that use products and technologies developed in the space sector as an intermediate input. An important trigger for this discussion was the growing use of embedded satellite signals (through Global Positioning System based products, for example) and data (e.g. through commercial geographic information systems) in different mass-market products and services (navigation apps in mobile devices, game apps in smartphones etc.). Direct-to-home satellite broadcasting is another example as major media players offer bundled services with cable, fibre and satellite solutions (see Box 2.1).

Two key recurring questions are:

- Should the scope of the space economy be limited to activities generating products and technologies intended to fulfil the functions of a space programme or in support of a space activity?
- Alternatively, should the definition also include industries producing digital products and services that are quite remote from traditional space activities, but which clearly rely on space capacities (satellite signals and data) to exist? In other words, should all the activities that use space services as an intermediate good be included in measurements of the space economy?

Within this context, the OECD Secretariat launched a new consultation process concerning the evolving definitions of the space sector and its derived activities. The consultation process involved more than 100 organisations from national administrations, business enterprises and industry associations. In parallel, several countries and agencies have also focused on what should be considered the space economy in their own definitions.

In 2020, the US Bureau of Economic Analysis (BEA) formulated the following definition when compiling their Space Economy Satellite Account (see the next sections for more on satellite accounts):

> *"The space economy consists of space-related goods and services, both public and private. This includes goods and services that:*

> - *are used in space, or directly support those used in space*
> - *require direct input from space to function, or directly support those that do*
> - *are associated with studying space" (Highfill, Jouard and Franks, 2020[2]).*

This definition enables the categorisation and identification of selected products and services that are part of the space economy. It opens up new questions for some products (e.g. there was debate with the US space industry on whether or not to include ground-based solar panels that require a space input for energy generation, i.e. the sunlight). But overall, it covers well a whole of range of space products and services.

Based on all these recent developments and the extensive international consultation process (see Chapter 1 for a recap), there was a broad consensus in favour of standardising the overarching concept of the "space economy" in order to promote a common understanding and a common vocabulary when distinguishing between different space activities. Therefore, the *Handbook* recommends taking a comprehensive approach to measurement.

The end-result of this analysis is a set of general concepts and definitions that should help stakeholders get a better sense of which activities and actors to include in their analysis of space activities including:

- two general segments of the space economy, which can be measured more or less readily in official and industry statistics, and a third one, which provides an indication of the growing space economy pervasiveness in the economy
- better defined categories of activities based on existing practices.

General concepts: Identifying the main sectors of space applications and the three main segments of the space economy

The following sections identify the main sectors of application of space activities and the three segments of the space economy for measurement purposes. They feature activities that may be more or less challenging to measure.

Main sectors of space applications

The different uses or applications of space activities evolve constantly as space technologies become increasingly embedded in systems and services used in routine activities. Using well-recognised definitions and experiences from different countries surveying their space economy, the most common space activities are the following:

- **Satellite communications:** The development and/or use of satellites and related subsystems to send signals to Earth for the purpose of fixed or mobile telecommunications services (voice, data, Internet, and multimedia) and broadcasting (TV and radio services, video services, Internet content).
- **Positioning, navigation and timing:** The development and/or use of satellites and related subsystems for localisation, positioning and timing services. Navigation is used for air, maritime and land transport, or the localisation of individuals and vehicles. It also provides a universal referential time and location standard for a number of systems.
- **Earth observation:** The development and/or use of satellites and related subsystems to measure and monitor Earth, including its climate, environment and people.
- **Space transportation:** The development and/or use of launch vehicles and related subsystems. This includes launch services, government and commercial spaceports, space adventure rides, as well as "last mile" and logistics services for transportation between orbits, etc.

- **Space exploration:** The development and/or use of crewed and uncrewed spacecraft (including space stations, rovers and probes) to explore the universe beyond Earth's atmosphere (e.g. the Moon, other planets, asteroids). Included in this sector are the International Space Station and astronaut-related activities.
- **Science:** The category includes a range of scientific activities including space science, i.e. the various scientific fields that relate to space flight or any phenomena occurring in space or on other planets (e.g. astrophysics, planetary science, space-related life science, space debris tracking); and space-related earth science, i.e. the various science fields that use space-based observations to study the physical and chemical constitution of the Earth and its atmosphere (e.g. atmospheric science, climate research).
- **Space technologies:** The category may include specific space system technologies that are used in various space missions, such as space nuclear systems (power, propulsion), solar electric propulsion, etc.
- **Generic technologies or components that may enable space capabilities:** Some of these are not initially destined for use on a specific space system or for a specific space application but may then lead to new products and services (e.g. artificial intelligence and data analytics software). This could be the case for early-phase research, small off-the-shelf components used in various systems, or services based on integrated applications.

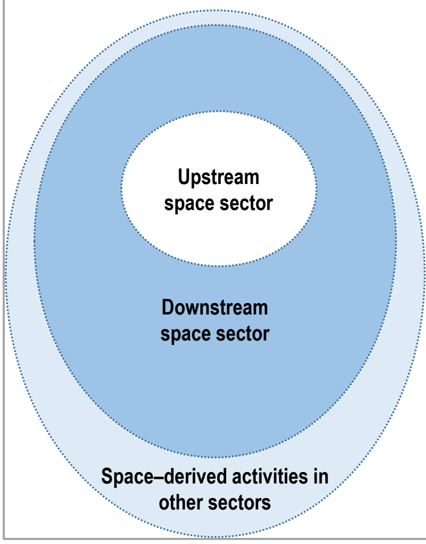
These are the main activities to focus on at this stage. Some organisations list “defence” as a separate application in order to distinguish between civil and military space activities. This *Handbook* does not make this distinction at the applications level but suggests the tracking of different types of procurers of space products and services including defence organisations (see Chapter 4 on surveys).

The three main segments of the space economy

The space economy concept is built upon decades of space operations via national space programmes and commercial activities and aims to improve international comparability across countries. It covers the main space activities listed in the previous section and divides the space economy loosely into three segments as shown in Figure 2.1. Using these general segments should allow for better international comparisons while also corresponding with existing data in many countries. The three segments are:

- The upstream segment representing the scientific and technological foundations of space programmes (e.g. science, R&D, manufacturing and launch): This segment is relatively easy to measure with official and industry statistics.
- The downstream segment (space infrastructure operations and “down-to-earth” products and services that directly rely on satellite data and signals to operate and function): Some, but not all, of the activities in this segment are easy to measure with official and industry statistics.
- Activities that are derived/induced from space activities but are not dependent on it to function (e.g. technology transfers from the space sector to the automotive or medical sectors): This segment is not easily or readily measurable and necessitates extra steps for measurement (more in Chapter 5). The advantage of mentioning and considering it, is that it could lead to a better understanding of the pervasiveness of a growing number of space activities in the broader economy.

Figure 2.1. Defining the main segments of the space economy



Scope	Activities
Upstream space sector = Scientific and technological foundations of space programmes, manufacturing and production of space infrastructure	Fundamental and applied research; scientific and engineering support; dedicated ancillary services (e.g. insurance); supply of materials and components; design and manufacturing of space equipment and subsystems; integration and supply of full systems; space launch
Downstream space sector = Daily operations of space infrastructure and "down-to-earth" activities that directly rely on the provision of a space capacity (satellite technology, signals or data) to exist and function	Operations of space and ground systems; supply of devices and products supporting consumer markets (e.g. GPS-enabled devices, set-top boxes, selected GIS); supply of services supporting consumer markets (e.g. satellite television broadcast)
Space-derived activities in other sectors = New activities in various economic sectors that derive from or have relied on space technology transfers	Activities/products/services derived from space technology, but not dependent on it to function (e.g. ad-hoc space technology transfers in the automotive or medical sectors)

An increasing number of organisations are starting to use the "mid-stream" concept (between upstream and downstream) to categorise space and ground system operations and describe activities along the value chain (Australian Space Agency, 2021[3]). These crucial activities constitute the link between satellites and terrestrial infrastructures. They may be categorised in either upstream or downstream activities depending on methodological choices. Here, the *Handbook* recommends these activities be part of the downstream segment (see the section on Downstream space activities).

Upstream space activities

Any space programme requires strong scientific and technological foundations ranging from basic research to full production of space and ground systems. These activities are considered the upstream segment and include the following categories:

- fundamental and applied research activities conducted at higher education institutions, public research organisations, and private and non-profit research organisations
- ancillary services such as finance, insurance and legal services and consultancies
- scientific and engineering support including the provision of research and development services, engineering services such as design and testing and similar activities
- supply of materials and components for space and ground systems, including both passive parts (cables, connectors, relays, etc.) and active parts (e.g. diodes, transistors, semiconductors)
- design and manufacture of space equipment and subsystems such as electronic and mechanic equipment and software for space and ground systems, as well as systems for spacecraft guidance, propulsion, power, communications, etc.
- integration and supply of full systems including complete satellites/orbital systems and launch vehicles as well as terrestrial systems such as control centres and telemetry, tracking and command stations.

These activities are conducted by the government sector, space business enterprises and the scientific community at large and they are essential enablers for downstream activities. Historically, upstream space activities have been the focus of space economy statistics put together by governments and industry associations. Recent and future space activities could also be included here, e.g. space tourism, on-orbit servicing, active debris removal, on-orbit manufacturing and resource extraction.

Table 2.1 below showcases selected upstream activities and the organisations involved in the segment.

Table 2.1. Selected activities, products and services in the upstream space segment

Main groups of activity	Subgroups	Selected products and services	Type of organisations involved
Research, engineering and other services	Fundamental and applied research	• Fundamental and applied research	Universities, public and not-for-profit research organisations
	Ancillary activities	• Insurance and legal services • Market research • Finance	Insurance, law and research consulting firms, venture capital firms
	Scientific and engineering support	• Research and development services • Engineering services (design, testing, etc.)	Engineering firms, universities, public research organisations and agencies
Space manufacturing	Supply of materials and components	• Materials and components for both space and ground systems: Passive parts (around 70% of components in space sub-systems: Cables, connectors, relays, capacitors, transformers, RF devices, etc.) and active parts (e.g. diodes, transistors, power converters, semiconductors)	Suppliers and component manufacturers. Includes both off-the-shelf and specialised suppliers
	Design and manufacturing of space equipment and subsystems	• Electronic equipment and software for space and ground systems • Spacecraft/satellite platform structure and data handling subsystem (e.g. on-board computer, interface unit, satellite and launcher electronics) • Guidance, navigation and control subsystems, and actuators (e.g. gyroscopes, sun and star sensors rendezvous- and docking sensor) • Power subsystems (e.g. electrical propulsion, power processing unit, solar array systems, photo voltaic assembly) • Communications subsystems (e.g. receivers and converters, fibre optic gyro, solid state power amplifier, microwave power module, downlink subsystem, transponders, quartz reference oscillators, antenna pointing mechanism) • Propulsion subsystems (e.g. propellant systems, tanks, valves, electric propulsion systems) • Other satellite payload specific subsystems	Equipment and subsystem manufacturers with increasing degree of specialisation, often also catering to aeronautics and defence Many SMEs; and in recent years, an increasing number of manufacturers of very small satellite subsystems
	Integration and supply of full systems	• Complete satellite/orbital systems • Launch vehicles (and related launch services) • Control centres and telemetry, tracking and command stations	+20 big actors worldwide, with suppliers often also catering to aeronautics and defence and governments generally forming an important part of the customer base. In recent years, increasing number of integrators of much smaller systems
Space launch and transportation		• Government and commercial spaceports	+10 licenced spaceports in the United States and several projects worldwide

Downstream space activities

Downstream space activities comprise the provision of products and services that rely on satellite signals or data, aimed at consumer and business markets. They include primarily satellite communications and precision, navigation and timing applications, but also earth observation products and services, which have greatly benefited from advances in artificial intelligence and cloud computing. As the range and diversity of commercial space applications have grown in the past five years, space downstream activities have attracted much attention, including from private investors. Downstream activities include:

- Space and ground systems operations: Satellite operations provide lease or sale of satellite capacity mainly for communications but also increasingly for earth observation. Ground systems constitute the link between satellites and terrestrial infrastructures with networks of ground stations at strategic positions (often polar or mid-latitude). Satellite operations firms may be active across the entire value chain, own their own satellites and ground stations for instance, and also provide products and services directly to customers.
- Data distribution services: A growing number of companies provide cloud computing powered platforms or services simplifying the access, use and distribution of (mainly geospatial (GIS)) products.
- Supply of devices and equipment supporting the consumer markets: Activities in this category include devices manufacturing (chipsets, terminals, global navigation satellite services (GNSS) equipment and other devices) and the development of software.
- Supply of services supporting the consumer markets: Direct-to-home (DTH) provision (television, radio, broadband – see Box 2.1); positioning, navigation and timing services provision; provision of electro-optical imagery (telemetry, tracking and command services). Current applications include cartography and mapping; logistics and distribution; sales and marketing; surveillance and security; timing and precision work; and communications.
- Supply of data added-value services: The processing of products and services from one or multiple data sources (satellite imagery/signals and in-situ observations, other sources of information) and transforming them into readily usable information. The same company may provide both raw and processed products and services. Many actors in this category do not consider themselves as space sector companies although their products depend on space signals or data.

The measurement challenge is particularly important for this segment of the space economy as the actual space-specific activities may be difficult to identify and may be easily over- or underestimated. An overview of selected downstream activities and organisations is presented in Table 2.2.

Table 2.2. Selected activities, products and services in the downstream space segment

Activity	Selected products and services	Examples of organisations
Operations of space and ground systems	• Satellite operations, including lease or sale of satellite capacity (telecom: Commercial fixed- and mobile satellite services operators; earth observation operators) • Provision of control centres services to third parties	More than 50 satellite communications operators around the world. Category also comprises ground station networks including domestic and foreign-owned ground stations as well as collaborative ground stations at polar and mid-latitude locations
Supply of devices and products supporting the consumer markets	• Very small aperture terminal networks • Satnav and telecom equipment and connectivity devices • Chipsets	Geospatial products, chipset and device manufacturers

Activity	Selected products and services	Examples of organisations
Supply of services supporting consumer markets	• Direct-to-home (DTH) services • Location-based signals services • Cloud-based services to host and/or process geospatial data • Data-derived commercial services providers (sometimes called value-adders: Telematics, surveying, meteorology)	Actors included in the space economy as far as a share of their activity directly relies on the provision of satellite signals or data. Providers of satellite broadcasting services tend to dominate this category in terms of revenues

Box 2.1. Satellite broadcasting as part of the space economy's downstream activities

Direct-to-home (DTH) satellite services such as satellite television represent an important commercial activity in both OECD member countries and partner economies. Converging information technologies are increasingly combining different infrastructures to provide content to final consumers. The broadcasting operators are often large groups with many telecommunication and media activities.

Should the satellite broadcasting activities of these large media groups, typically unrelated to the space industry, be included as downstream activities of the space economy?

As compared to many other downstream space activities, demonstrating the link and reliance of these products and services on a space capacity is actually quite straightforward. Satellite television uses satellite links, although convergent technologies blur some of the packaging options (i.e. cable and fibre). Programming transmission, technology and fixed networks are recurring costs for satellite television broadcasters. As distributors of media information, most have long-term contractual commitments such as expenditures planned for several years in television rights. They also lease satellite transponder capacity. The DTH broadcasters contract out the commercial satellite operations for digital transmissions to their retail subscribers and free-to-air broadcast services.

By analysing the annual accounts of these large telecommunications groups, a formal link to a space activity may be documented transponder agreements such as operating leases and specific transponder prepayments. Although estimates can be made, it is more challenging to determine the share of revenues that are directly derived from the use of satellites. A number of consulting firms that serve telecommunication satellite operators and manufacturers provide regular market studies on existing and planned satellite transponders' usage and the market prices involved. Such studies provide a first indication of the share of revenues derived from space activities. To refine data on broadcasters, one avenue is to examine annual reports where some details are publicly available. If such details are not publicly available, dedicated surveys of DTH satellite service providers may be necessary.

Although DTH activities represent a strong case-study in how satellites benefit consumer markets, the significance of these commercial satellite broadcasting activities should not be overestimated (i.e. these activities still represent overall very small percentages of the multi-billion revenues generated by the large media and telecommunication groups). However, when relevant, the value associated with commercial satellite use should be clearly identified and included in estimates of the space economy's downstream activities.

Other space-derived activities

The third and last segment consists of broad economic activities that were developed at least partially thanks to the use of space technologies. This segment is quite distinct from the upstream space sector, as it usually involves users who may have benefited from space technology transfers to create their own new products (Olivari, Jolly and Undseth, 2021[4]). These outcomes can be measured by specific surveys and impact assessment studies (see Chapter 5).

The automotive and medical sectors, for instance, are home to many derived products that originally benefited from initial investments in the upstream space segment. Different monitoring techniques may be applied to keeping track of these particular indirect outcomes of space research and development (some of which are also outlined in Chapter 5).

Box 2.2. Defining a "space company"

Defining a "space company" has been a challenge for a long time. Very often business enterprises involved in the manufacturing of space products and/or in the provision of space-related services are also involved in other areas of the economy. They may derive only a part of their revenues from space activities. In other words, most business enterprises that produce upstream products and services for the space economy also produce goods and services beyond the space economy. As an illustration, it is not possible to count the total revenues of large aerospace manufacturers or media groups, as being entirely part of the space economy. To avoid overestimation, a major point is to check whether a space product or data is an integral part of the final service sold, and if so, to determine the value of the space item in the final output of the company.

In its 2013 study of almost 4 000 organisations in the US space sector, the US Department of Commerce found that some 71% of respondents were serving more than one market segment including aircraft, electronics, energy, missiles, ground vehicles, ships etc. (US Department of Commerce, 2013[5]). The rapid digitalisation of the downstream sector poses even greater challenges for the delineation between the space and non-space economies.

Much attention has been given to "new space" actors in recent years. New space actors include, generally speaking, upstream and downstream start-ups and new entrants from other areas (information and communications technologies firms including those engaged in data analytics in particular). The bulk of these new entrants may be identified through information on the recipients of government grants and services, participants in (government)-organised challenges, winners of prizes and different types of start-up support (incubators, accelerators, etc.), and following the investments of venture capital. As an illustration, SpaceX was the fourth largest NASA contractor in 2020 (by procurement awards), after Boeing, Lockheed Martin and Jacobs Technology, a technical professional services firm (NASA, 2021[6]).

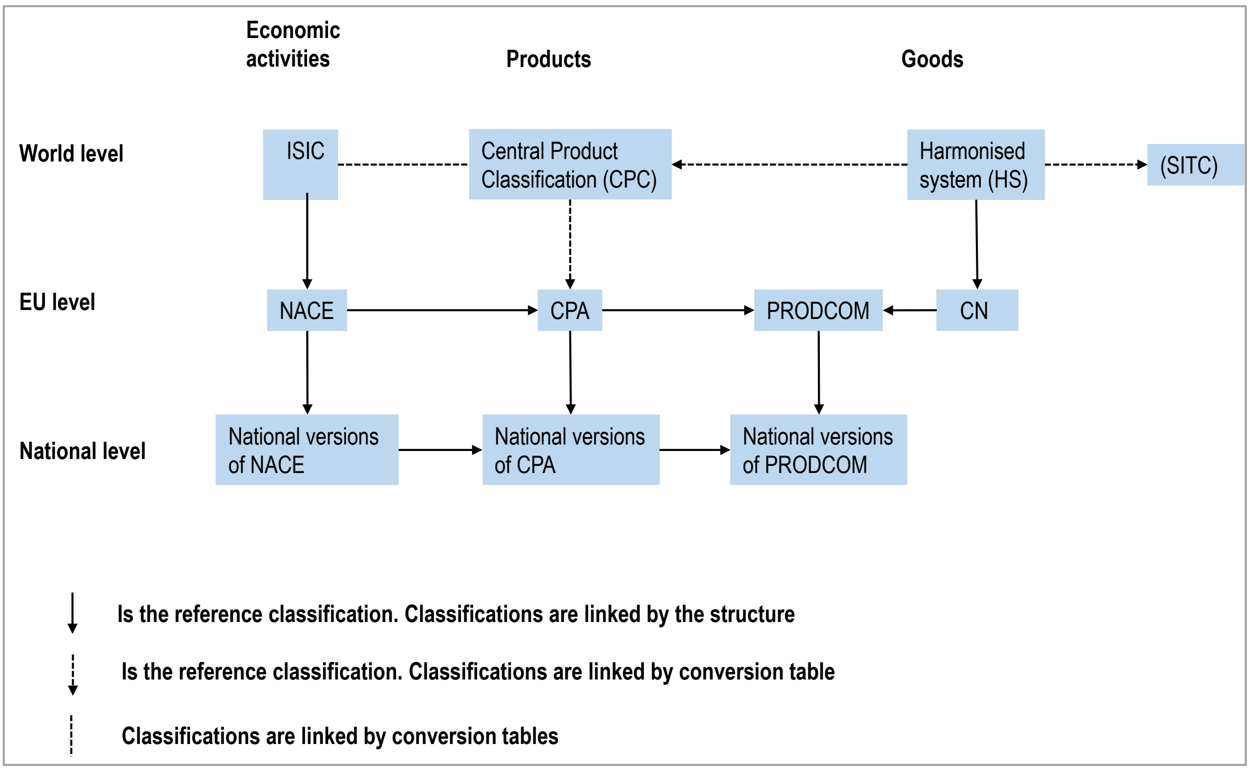
Measurement strategies: Identifying space activities, products and services in statistical information systems

Statistical classification systems provide definitions of the categories of economic activities and other related concepts used in economic statistics. Because of the relatively small size of the space economy, as well as the highly dispersed and varied nature of space activities, the production of space-related products and services (or commodities) tend to be spread across a wide number of economic activities. This makes it challenging to identify and distinguish space activities, products and services in statistics that rely upon existing classifications. However, official statistics based on existing statistical classification systems may still be used to form a baseline and allow comparisons across the economy as shown in the next sections.

International statistical classifications and their role in categorising the space economy

Many studies of the space economy use existing statistical classification systems and relevant codes for economic activities as the starting point of their analysis. Examples of classifications include the United Nations' International Standard Industrial Classification of All Economic Activities (currently ISIC Revision 4), the Statistical Classification of Economic Activities in the European Community (NACE Rev. 2.1), and the International Standard Classification of Occupations (ISCO-88). These are carefully coordinated with the System of National Accounts (SNA), which is the standard framework for economic accounting in OECD member countries. An overview of the links between international classifications recommended in the European System of National Accounts can be seen in Figure 2.2.

Figure 2.2 Overview of relationships between different international and European classifications



Source: Eurostat (2008[7]), "NACE Rev. 2: Statistical classification of economic activities in the European Community", http://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF.

ISIC consists of a coherent and consistent classification structure of economic activities based on a set of internationally agreed concepts, definitions, principles and classification rules. The categories of economic activity are subdivided in a hierarchical, four-level structure of mutually exclusive categories. None of these categories is fully concordant with space activities even at the most detailed level. ISIC categories that include activities considered part of both the upstream and downstream segments of the space economy include aerospace, electronics, telecommunications and even armaments since rockets are counted as weapons in many countries (e.g. missile technology). Table 2.3 contains ISIC codes for categories of economic activity that partially include space activity for high-level international comparisons.

Since the publication of the first *OECD Handbook on Measuring the Space Economy*, an updated ISIC classification has been agreed upon. The current edition of ISIC (Rev. 4) (UN Department of Economic and Social Affairs, 2008[8]) includes a new category on satellite communications. The class 6130 "Satellite telecommunications activities" comprises three space-related components:

- the use of a satellite telecommunications infrastructure for operating, maintaining or providing access to facilities for the transmission of voice, data, text, sound and video
- the use of direct-to-home satellite systems for the delivery of visual, aural or textual programming received from cable networks, local television stations or radio networks to consumers (it is detailed in the class 6130 description that the units classified here do not generally originate programming material themselves)
- the provision of Internet access by the operator of the satellite infrastructure.

ISIC Rev. 4 is considered a reference classification for most regional and national classification systems and it enables international comparisons between statistics categorised accordingly. The Statistical Classification of Economic Activities in the European Community (NACE) mostly corresponds with ISIC Rev.4 and includes more detailed categories suitable for European users of the classification at lower levels. The North American Industry Classification System (NAICS) also partially relates to ISIC Rev.4 and is almost entirely concordant up to the two-digit level of detail. There is also concordance with the Australian and New Zealand Standard Industrial Classification (ANZSIC) and other regional and national classifications.

Findings from industry surveys and studies indicate that the bulk of space activity tends to be measured under ISIC Rev.4 Section I: Information and communications (covering satellite communications) and Section C: Manufacturing (covering space manufacturing) (see Chapter 4 on industry surveys).

As of early 2022, new revision processes are underway for almost all classification systems to take into account the growing digitalisation of the economy in official statistics (i.e. ISIC, NACE, NAICS and also CPC classifications).

Table 2.3. Selected two-digit space-related ISIC codes for international comparisons

Examples of space activities	ISIC Rev. 4 section	ISIC Rev. 4, two-digit code	ISIC description
Fundamental and applied research	M: Professional, scientific and technical activities	72	Scientific research and development
Ancillary activities (e.g. space insurance)	K: Financial and insurance activities	65	Insurance, reinsurance and pension funding, except compulsory social security
Research and development services, engineering services (testing, design)	M: Professional, scientific and technical activities	71	Architectural and engineering activities; technical testing and analysis
Supply of components and equipment for space systems	C: Manufacturing	20	Manufacture of chemicals and chemical products
		22	Manufacture of rubber and plastics products
		25	Manufacture of fabricated metal products, except machinery and equipment
		26	Manufacture of computer, electronic and optical products
		27	Manufacture of electrical equipment
		28	Manufacture of machinery and equipment n.e.c.
Integration and supply of full space systems (e.g. launchers, satellites)		30	Manufacture of other transport equipment
Construction of space facilities (e.g. spaceports and other ground facilities, observatories)	F: Construction	42	Civil engineering
Space launch activities (freight transport and space tourism)	H: Transportation and storage	51	Air transport
		52	Warehousing and support activities for transportation

Examples of space activities	ISIC Rev. 4 section	ISIC Rev. 4, two-digit code	ISIC description
Operation of space systems	I: Information and communication	61	Telecommunications
Supply of devices and products supporting consumer markets (e.g. GNSS chipsets and devices)[1]	C: Manufacturing	26	Manufacture of computer, electronic and optical products
Supply of services supporting consumer markets (e.g. DTH providers, data-derived commercial services)[2]	I: Information and communication	60	Programming and broadcasting activities
		61	Telecommunications
		63	Information service activities
	M: Professional, scientific and technical activities	71	Architectural and engineering activities; technical testing and analysis
		74	Other professional, scientific and technical activities

1. Includes both intermediary inputs to final products such as cars (e.g. GNSS receivers) and consumer devices (GNSS devices, satellite phones). 2. Only includes activities that directly rely on the provision of a space capacity (space technology, signals or data) to exist and function.

The issue of aggregated categories can be found also in other international classifications such as the United Nation's Central Product Classification Version 2.1 (CPC Ver.2.1) and the 2017 Harmonized Commodity Description and Coding System (HS 2017) of the World Customs Organization. Table 2.4 provides the equivalences between the main classification systems.

Table 2.4. Selected categories of space products and services in international classifications

Space activity	CPC Ver.2.1	ISIC 4	HS 2017
Fundamental and applied research	81111 Basic research services in physical sciences	7210	-
	81114 Basic research services in engineering and technology	7210	-
	81121 Applied research services in physical sciences	7210	-
	81124 Applied research services in engineering and technology	7210	-
Ancillary services	71332 Marine, aviation, and other transport insurance services (Includes underwriting of satellite launching insurance policies)	6512	-
Scientific and engineering support	81131 Experimental development services in physical sciences	7210	-
	81134 Experimental development services in engineering and technology	7210	-
	83322 Engineering services for industrial and manufacturing projects (includes equipment for space vehicles)	7110	-
	48253 Instruments and apparatus for physical or chemical analysis, for measuring or checking viscosity, porosity, expansion, surface tension or the like, or for measuring or checking quantities of heat, sound or light	2651	9027.1, 9027.2, 9027.3,9027.5, 9027.8
	83442 Testing and analysis services of physical properties (of materials such as metals, plastics, etc.)	7120	-
	83443 Testing and analysis services of integrated mechanical and electrical systems (of complete machinery and equipment)	7120	-
	83449 Other technical testing and analysis services (does not alter the object being tested, e.g. certification of aircraft, etc.)	7120	-
Supply of materials and components	34210 Hydrogen, nitrogen, oxygen, carbon dioxide and rare gases; inorganic oxygen compounds of non-metals n.e.c.	2011	2804.1, 2804.21, 2804.29, 2804.3, 2804.4
	89200 Moulding, pressing, stamping, extruding and similar plastic manufacturing services (includes carbon fibre)	2220	-
	89330 Metal forging, pressing, stamping, roll forming and powder metallurgy services	2591	-
	48315 Liquid crystal devices n.e.c.; lasers, except laser diodes; other optical appliances and instruments n.e.c.	2610, 2670	9013.1, 9013.2, 9013.8

Space activity	CPC Ver.2.1	ISIC 4	HS 2017
	47150 Diodes, transistors and similar semi-conductor devices; photosensitive semi-conductor devices; light emitting diodes; mounted piezo-electric crystals	2610	8541.1, 8541.21, 8541.29, 8541.3, 8541.4, 8541.5, 8541.6
	46212 Electrical apparatus for switching or protecting electrical circuits, for making connexions to or in electrical circuits, for a voltage not exceeding 1000 V	2710	8536.1, 8536.2, 8536.3, 8536.41, 8536.49, 8536.5, 85.61, 8536.69
	46320 Coaxial cable and other coaxial electric conductors	2732	8544.2
Design and manufacturing of space equipment and subsystems	48219 Other surveying, hydrographic, oceanographic, hydrological, meteorological or geophysical instruments and appliances	2651	9015.4, 9015.8
	4828 Parts and accessories for the goods of classes 4821 and 4823 to 4826	2651	
	48211 Direction finding compasses; other navigational instruments and appliances	2651	9014.1, 9014.2, 9014.8
	48242 Cathode-ray oscilloscopes and cathode-ray oscillographs	2651	9030.2
	48314 Binoculars, monoculars and other optical telescopes; other astronomical instruments, except instruments for radioastronomy; compound optical microscopes	2670	9005.1, 9005.8
	48244 Instruments and apparatus (except cathode-ray oscilloscopes and oscillographs) for telecommunications	2651	9030.4
	49640 Parts of aircraft and spacecraft	3030	8803
	4313 Motors and engines for aircraft and spacecraft	3030	-
Integration and supply of full systems	49630 Spacecraft and spacecraft launch vehicles	3030	8802.6
Space launch	53290 Other civil engineering works (includes. satellite launching sites)	4290	-
	65320 Space transport services of freight (i.e. launching and placing of satellites in space)	5120	-
	64250 Space transport services of passengers	5110	-
	67640 Supporting services for space transport	5223	-
	83323 Engineering services for transportation projects (includes space transportation projects)	7110	-
Satellite operations	84150 Data transmission services	6130	-
	84190 Other telecommunications services (includes Satellite tracking services)	6110, 6120, 6130, 6190	-
Downstream products and devices (and related services)	47223 Other telephone sets and apparatus for transmission or reception of voice, images or other data, including apparatus for communication in a wired or wireless network (such as a local or wide area network) (includes: Field telephones (military))	2610, 2630	8517.18 8517.61 8517.62 8517.69
	48220 Radar apparatus, radio navigational aid apparatus and radio remote control apparatus (includes "satellite linked auto security device used to send signals via satellite to a specific vehicle to carry out electromechanical commands on that vehicle based on an encoded signal)	2651	8526.91
	54614 Residential antenna installation services (includes Installation of satellite dishes)	4321	-
Downstream services for earth observation; navigation, timing; and satellite telecommunications	83159 Other hosting and IT infrastructure provisioning services	6311	-
	83430 Weather forecasting and meteorological services (more than satellite data activities)	7490	-
	83931 Environmental consulting services		
	83421 Surface surveying services (includes collection of data by satellite)	7110	-
	83325 Engineering services for telecommunications and broadcasting projects (includes satellite radio systems and direct-broadcast satellite systems)	7110	-
	84131 Mobile voice services (includes satellite phones)	6120	-
	84140 Private network services	6130	-
	84150 Data transmission services	6130	-

Space activity	CPC Ver.2.1	ISIC 4	HS 2017
	84190 Other telecommunications services (includes satellite tracking services)	6110, 6120, 6130, 6190	-
	84221 Narrowband Internet access services, downstream speeds < 256 kbits/s (includes satellite fixed wireless Internet services)	6110	-
	84222 Broadband Internet access services, downstream speeds > 256 kbits/s (includes satellite fixed wireless Internet services)	6110	-
	84290 Other Internet telecommunications services	6130	-
	8463 Broadcasting services and multi-channel programme distribution services (includes home programme distribution services, basic and discretionary programming)	6010, 6020	-
	91134 Public administrative services related to transport and communications (includes administrative services related to satellite communications)	8413	-

Notes: The classifications codes usually include more than just space-related products and services. N.e.c. means "not elsewhere classified".

A challenge to the use of official statistics in the measurement of the space economy is that space activities and products are not always found in the statistical classification systems used by national statistical offices. The space economy is therefore not readily visible in most of the official statistics produced. This can, however, be circumvented through additional statistical analysis.

Some national and regional classification systems provide more space-related detail than the international classifications. NAICS, for example, categorises the manufacture of space vehicles and launchers and satellite communications, but most downstream activities, such as earth observation, remain unidentified.

Below is a non-exhaustive list of four-digit ISIC codes that contain space activities together with the equivalent regional codes for North America (NAICS) and Europe (NACE). At four-digit levels, activities tend to be grouped together when they share a common process for producing products or services using similar technologies.

- Most notable is ISIC code 6130: "Satellite telecommunications activities", which is the only ISIC four-digit code that is fully space-related.
- The other codes include 3030: "Manufacture of air and spacecraft and related machinery", 6020: "Television programming and broadcasting activities" and finally, 2651: "Manufacture of measuring, testing, navigating and control equipment", which covers the manufacture of chipsets and devices for global navigation satellite systems, and which accounts for a significant share of recent growth recorded in space economy estimates.

With the exception of ISIC 2651, these codes tend to represent activities producing goods and services used in final demand (i.e. the list does not include products and services consumed as inputs in the production of others, so called intermediate consumption) (United Nations Statistical Commission, 2009[9]).

In some cases, national/regional classifications provide more detailed categories for certain space activities. For example, NACE 51.22: "Space transport" provides more detail than ISIC 5120: "Freight transport", while NAICS 336414: "Guided missile and space vehicle manufacturing" provides more detail than ISIC 3030: "Manufacture of air and spacecraft and related machinery".

Despite their lack of space-related detail, existing statistical classification systems remain an important starting point for economic analysis of the space economy and for targeted surveys of organisations operating in the space economy. Many companies developing downstream space applications are for instance registered as data-processing companies under the ISIC four-digit code 6311: "Data processing, hosting and related activities". In turn, targeted surveys can be used to collect basic information on the share of space activities in total activities of individual organisations, which subsequently can be linked to microdata that are already available in statistical offices for the production of official statistics. This provides the opportunity to generate statistics at more aggregated levels. This method has recently been applied in a study on the space economy in the Netherlands (Dialogic, 2020[10]).

Table 2.5. Selected four-digit ISIC codes for space activities and their NAICS and NACE equivalents

ISIC Rev. 4, four-digit code	ISIC description	Full/partial coverage	Space activities	Selected products and services	Equivalent regional codes	
					NAICS (North America)	NACE (Europe)
6130	Satellite telecommunications activities	Full	Operation of space and ground systems	Satellite operations	517410[1]	61.30[1]
6020	Television programming and broadcasting activities	Partial	Supply of services supporting consumer markets	Direct-to-home satellite broadcasting	517311	60.20
3030	Manufacture of air and spacecraft and related machinery	Partial	Integration and supply of full space systems	Satellites, launchers	336414[2] 336415[2] 336419[2]	30.30
2651	Manufacture of measuring, testing, navigating and control equipment	Partial	Supply of devices and products supporting consumer markets	GNSS chipsets, GNSS consumer devices	334511	26.51
5120	Freight air transport	Partial	Space launch activities	Space launch	481212	51.22[1]

1. Full coverage, 2. Includes both space and guided missile manufacturing.

A step further: Building a “satellite account” for space activity

The previous sections have shown that space activities are not readily visible in official statistics. Once the relevant categories that contain space activity in official statistics have been identified, the share of each of these activities and products that is attributable to the space economy can be estimated. This is where the national accounts framework can assist.

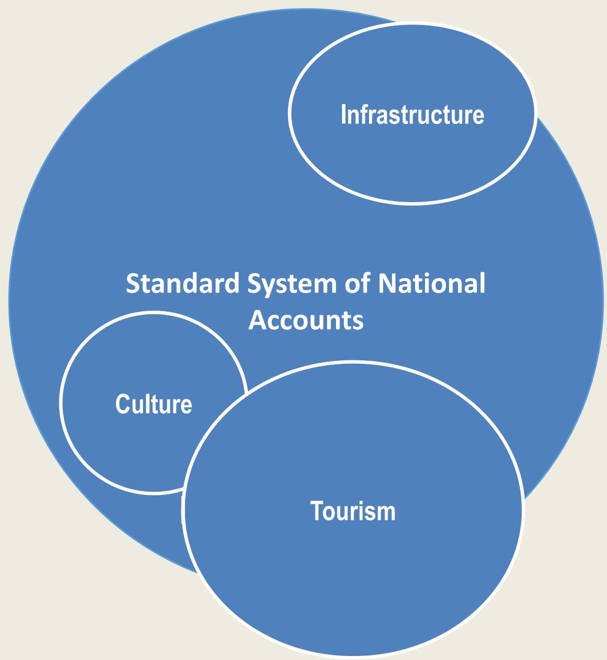
The system of national accounts aims to measure every economic activity, even if the fine details may not be readily visible. The relationship between activities and products is made explicit through “supply and use” tables (SUTs). SUTs are produced by national statistical offices and offer a comprehensive picture of the inner workings of a national economy. SUTs record how the supply of different kinds of products and services originate from domestic industries and imports and how the use of these products and services is split between various intermediate or final uses (including exports).

The most comprehensive way to benefit from the national accounting system is through the development of a “satellite account” for space economic activities. Satellite accounts are linked to the core national accounts but provide a more detailed description of a specific economic function or theme (e.g. environment, tourism, health, ocean economy, transport) (van de Ven, 2021[11]). Their link to the traditional system of national accounts makes it possible to compare the contribution of otherwise invisible areas to the economy as a whole (see Box 2.3).

Box 2.3. What is a satellite account?

A satellite account can be used to unearth fields or aspects of behaviour that are fully or partially hidden in the central national accounting framework. Tourism is a typical example. Many aspects of tourism are covered in detailed classifications of activities, products and purposes, but rarely appear separately with distinct classification codes. Instead of overburdening the central framework with too many subdivisions and detail, the System of National Accounts recommends the creation of satellite accounts that are consistent with, but not fully integrated, in the central framework (van de Ven, 2021[11]).

Figure 2.3. Standard System of National Accounts and thematic satellite accounts



Source: Statistics Canada (2019[12]), "In-depth review of satellite accounting", https://www.unece.org/stats/ces/in-depth-reviews/satellite-accounting.html.

Satellite accounts can provide more detail, rearrange concepts from the central statistical framework and provide supplementary information on specific domains of economic activities. The main motivation is to understand the structure and/or economic performance of an activity and/or sector. The most common satellite accounts cover tourism, environmental-economic linkages and health. Accounts have also been created for education and training, transport, aviation, and the non-profit sector. In terms of complexity, they can range from simple tables to an extended set of accounts. Data are often compiled less frequently and regularly than for standard national accounts.

Sources: Van de Ven (2021[11]), "Developing thematic satellite accounts", https://dx.doi.org/10.1787/b833cbfa-en; United Nations Statistical Commission (2009[9]), *System of National Accounts*, https://unstats.un.org/unsd/nationalaccount/docs/sna2008.pdf; and Statistics Canada (2019[12]), "In-depth review of satellite accounting",https://www.unece.org/stats/ces/in-depth-reviews/satellite-accounting.html.

In the United States, the Bureau of Economic Analysis has led an extensive project to measure the US space economy and its contribution to the national economy through two editions of a satellite account (BEA, 2020[13]). In addition to estimating the contribution of the space economy to the national gross domestic product (GDP), the US Space Economy Satellite Account (SESA) provides data on gross output, compensation, and employment in space industries (Highfill, Jouard and Franks, 2020[2]). The statistics produced through the account are consistent with the BEA's core economic measures and can be used to compare the space sector to other US industries and the economy overall. Building the SESA account included isolating spending on space production by rearranging the BEA's existing SUTs. The process involved the following elements:

- Relevant products and services ("commodities") were identified within BEA SUTs (Table 2.6). BEA consulted extensively with other public organisations (including the OECD) and industry experts in order to select the commodities measured (BEA, 2020[13]). Some 200 commodity codes and 28 NAICS regional industrial classification codes with space-related content have been identified. They are listed for information in Annex 2.A.
- As most commodity categories include both space and non-space components, external data sources, mainly information on space-related revenue or spending, were used to estimate the share of each commodity that could be assigned to the space economy in the SUT.
- Finally, BEA SUTs were used to determine total economic activity by industry.

Table 2.6. Industries and commodities included in the US space economy estimates with principal data sources

NAICS codes	Primary industries	Brief description of commodities	Principal data sources
51	Information	Telecommunications, broadcasting, software	Bureau of Labor Statistics (BLS) Occupational Employment Survey (OES); Federal Communications Commission "Internet Access Services" reports; Securities and Exchange Commission 10-K filings; Bureau of Economic Analysis supply-use tables
31-33, 42	Manufacturing, retail trade, and wholesale trade	Space vehicles; space weapon systems; satellites; ground equipment; search, detection, navigation, and guidance systems (GPS/PNT equipment)	Economic Census product line data; BEA supply-use tables
90	Government	Military, civilian, federally funded research and development centres	Public budget documents; National Science Foundation (NSF) Survey of Federal Funds for Research and Development; BEA supply-use tables
54	Professional and business services	Research and development; engineering and technical services; computer systems design; geophysical surveying and mapping services	BLS OES; NSF Survey of Federal Funds for Research and Development; NSF Business Enterprise Research and Development Survey; BEA supply-use tables
23	Construction	Space facilities, observatories, planetariums	Census Value of Construction Put in Place; BEA supply-use tables
	Other various service industries	Launch services, insurance, education, observatories, planetariums	Federal Aviation Administration "Annual Compendium of Commercial Space Transportation"; MITRE launch demand model; National Center for Education Statistics Integrated Post-Secondary Education Data System; public documents; BEA supply-use tables

Note: The table generally only includes final demand commodities, because intermediate demand commodities will be accounted for when using supply-use tables. However, for some commodities, only the value of the intermediate input has been included, and not the final demand commodity (e.g. GPS receivers for mobile phones and cars).
Source: Adapted from Highfill et al. (2020[2]), "Preliminary estimates of the U.S. space economy, 2012–2018", https://apps.bea.gov/scb/2020/12-december/1220-space-economy.htm.

Estimates for 2019 show that the US space economy accounted for USD 194.6 billion of gross output, contributed 0.6 percent (USD 120.3 billion) to current-dollar GDP and supported more than 356 000 private sector jobs (Highfill, Jouard and Franks, 2022[14]). Gross outputs by industry are summarised in Table 2.7.

Table 2.7. US space economy gross output by industry

Estimates in USD million (current)

Industry activities	2019
Space economy[1]	**194 596**
Agriculture, forestry, fishing, hunting, mining, and utilities	7
Utilities	2
Construction	980
Manufacturing	51 158
Of which:	
Computer and electronic products[2]	30 030
Other transportation equipment[3]	18 224
Wholesale trade	31 587
Retail trade	2 280
Transportation and warehousing	1 329
Information	59 704
Of which:	
Wired telecommunications carriers[4]	38 284
Satellite telecommunications	6 461
Finance, insurance, real estate, rental, and leasing	349
Professional and business services	6 370
Educational services	2 701
Health care and social assistance	87
Arts, entertainment, recreation, accommodation, food services and other services	140
Other services, except government	8
Government[5]	37 894
Federal	34 771
State and local	3 124
Private industries	
Space economy excluding satellite television, satellite radio, and educational services[6]	**148 683**

1. According to the BEA definition, the space economy consists of space-related products and services, both public and private. This includes goods and services that are used in space, or directly support those used in space, require direct input from space to function or directly support those that do, and/or are associated with studying space. 2. Includes manufacturing of satellites; ground equipment; search, detection, navigation, and guidance systems (GPS/PNT equipment). 3. Includes manufacturing of space vehicles and space weapons systems (intercontinental ballistic missiles). 4. Includes direct-to-home satellite television services. 5. Includes spending on personnel, operations, and maintenance. Government spending on private-sector investment (structures, equipment, intellectual property) is included within the individual industries. 6. This value represents a narrower interpretation of the "Space Economy" definition. These commodities are primarily produced by the Information and Educational services industries.

Source: Highfill et al. (2022[14]), "Updated and revised estimates of the US space economy, 2012–2019", https://www.bea.gov/system/files/2022-01/Space-Economy-2012-2019.pdf.

The US satellite account represents a detailed estimation of the size of the space economy and is the first such account constructed in the world. Since its publication, a number of countries and organisations have started to explore the satellite accounting approach in coordination with national and regional statistical offices.

As an illustration, the French space agency (CNES) has recently begun a partnership with the French National Institute of Statistics and Economic Studies (INSEE) to develop a new strategy for measuring the space economy using a satellite account approach. Although the INSEE has led surveys on the aeronautics and space sector for decades, policy demand for detailed data on the French space economy is increasing (INSEE, 2021[15]). The space economy is experiencing rapid changes, and it is of growing strategic importance in French and European autonomy. It is also, like aeronautics, included into a series of large-scale governmental recovery plans following the COVID-19 crisis. The CNES and the INSEE will start in 2022 by targeting the upstream segment, but the goal is to extend the effort and include the downstream segment in the near future (Lafaye, 2021[16]). As another example, the European Space Agency has started co-operating with Eurostat to explore the possible development of a European-wide space economy satellite account, with a first workshop held in March 2022.

Key take-aways to support space economy measurement strategies

The preceding sections have illustrated concepts and definitions for space activities and outlined some of the ways that official statistics can be used in the measurement of the space economy. There are several significant challenges involved in this type of measurement.

With some minor exceptions (e.g. ISIC code 6130: "Satellite operations"), existing statistical classification systems do not define space activities in isolation to all other related activities. As noted in the previous *Handbook*, changing classifications by creating codes for specific space activities is a possibility, as the ISIC classification, for instance, is revised at regular intervals (OECD, 2012[1]). It is, however, a long process necessitating co-operation and support from national statistical agencies and will not guarantee that statistics will be produced at the required level of detail.

Targeted surveys and impact studies based on the results are likely to remain the most effective approach for analysing the space economy for most countries, as a first step: Industry surveys can provide very useful data points for developing potential future satellite accounts. Without the type of information collected in industry surveys, national statistical offices are unlikely to be able to produce an eventual satellite account. Chapter 3 provides more information on the cast of actors in the space economy, while Chapter 4 provides lessons learnt from countries and well-established industry associations on pursuing survey-based measurement of the space economy.

Space and statistical agencies are encouraged to be innovative in their use of different official data sources: Combining more granular data from administrative records with official data and tools emanating from the system of national accounts is likely to provide important results to policy makers as the US Space Satellite Account demonstrates well. Projects focused on identifying the contribution of space activities to national economies through national accounting frameworks can provide new and important information on the role played by the space economy in the wider economy. However, this type of study requires the active involvement of national statistical agencies with national space communities, and sustained funding.

Providing support for data collection and analysis represents the key focus in the following chapters of the *Handbook*.

Annex 2.A. 200 Commodity codes used for the US Space Economy Satellite Account

When launching a satellite account, a list of adequate commodities needs to be identified to build up statistical tables (Highfill, Jouard and Franks, 2020[2]). As part of the US Space Economy Satellite Account (SESA), the US Bureau of Economic Analysis has (BEA) developed, with the support of many stakeholders in the space community and beyond, a list of 200 commodity codes that relate to space activities. These commodities and their codes are provided below for information purposes. They use long "NAICS-based codes", as in the North American Industry Classification System (NAICS), US industries are defined at the six-digit level. For use in its economic census and survey programmes, a number of administrations, including the BEA, have developed "NAICS-based codes" with codes greater than six digits to allow detailed analysis.

Annex Table 2.A.1. List of space commodities used in the US Space Economy Satellite Account

Commodity code	Commodity description
2332711	New air transportation structures – private
2332712	New air transportation structures – federal
2332713	New air transportation structures – S&L
5151102	Air-time sales for the broadcasting of radio program content
5151104	Public and non-commercial programming services – Radio (includes contributions, gifts, and grants)
5151202	Air-time sales for the broadcasting of television program content
5151204	Public and non-commercial programming services – TV (includes contributions, gifts, and grants)
5171101	Basic fixed local telephony (other than telecom resellers) – (Includes subscriber line and calling feature charges)
5171102	Basic fixed long distance and all distance telephony (other than telecom resellers)
5171104	Multichannel programming distribution services (analog and digital) (includes start-up and reconnect fees)
5171109	Broadband (always on) internet access services
5174101	Satellite telecommunications services – (includes carrier services and private network services of satellite telecommunications)
5413301	Engineering services
5415111	Custom computer programming
5415113	Own-account software
5419909	All other professional, scientific, and technical services
23326221	New other educational structures, incl. museums and libraries – private
23326222	New other educational structures, incl. museums and libraries – federal
23326223	New other educational structures, incl. museums and libraries – S&L
48100011	Air transportation, passenger transport-domestic
48100041	Air transportation, other
51121011	Application software publishing (other than games)
51121012	System software publishing
51511035	Licensing of rights to broadcast radio programs
51512035	Licensing of rights to broadcast television programs
51521035	Licensing of rights to distribute specialty television or audio programming content
51711010	Internet telephony
51711011	Force account, telephone equipment installation
51711039400	Licensing of rights to use intellectual property of wired telecom carriers
51791139400	Licensing of rights to use intellectual property of telecom resellers
51791939400	Licensing of rights to use intellectual property of all other telecommunications

Commodity code	Commodity description
54133039400	Licensing of rights to use intellectual property of engineering services
54137039400	Licensing of rights to use intellectual property of surveying and mapping (except geophysical) services
3333143333143	All other miscellaneous optical instruments and lenses
3341113341111	Host computers, multiusers (mainframes, super computers, medium scale systems, UNIX servers, PC servers)
3341113341117	Single user computers, microprocessor-based, capable of supporting attached peripherals (personal computers, workstations, portable computers)
3341183341181	Computer terminals (excl. parts/attachments/accessories/etc.)
3342203342205	Radio station equipment including satellite, airborne and earth-based (fixed and mobile)
3342903342903	Intercommunications systems, including inductive paging systems (selective paging), except telephone and telegraph
3345113345111	Aeronautical, nautical, and navigational Instruments not sending or receiving radio signals
3345113345113	Search, detection, navigation, and guidance systems
3345193345192	Aircraft engine instruments (except flight)
3345193345194	Physical properties testing and inspection equipment and kinematic testing and measuring equipment
3345193345199	Survey/drafting instruments/apparatus, incl. photogrammetric
3364133364131	Aircraft propellers and helicopter rotors
3364133364136	Aircraft parts and auxiliary equipment, excl. hydraulic and pneumatic subassemblies
33411833411841	Parts, attachments, and accessories for computer terminals (except point-of-sale and funds-transfer devices)
33451933451991	Parts and components for drafting and photogrammetric and geodetic instruments
33641433641411	Complete guided missiles
33641433641451	Other services on complete guided missiles
33641433641473	Complete space vehicles (excluding propulsion systems)
33641533641511	Complete missile or space vehicle engines – US military
33641533641512	Complete missile or space vehicle engines – US nonmilitary
33641533641513	Complete missile or space vehicle engines – other customers
334516334516167	Parts-components and accessories for analytical and scientific instruments, sold separately
336419336419112	Missile/space vehicles airframes/capsules – US military
3342203342202199	Broadcast, studio parts and accessories
3342203342209109	Antenna systems, sold separately
3345193345195120	Physical properties testing and inspection equipment and kinematic testing and measuring equipment
3364153364155100	Other services, complete missiles/space veh. eng./prop. units
3364153364157101	Missile and space vehicle engines or propulsion parts and accessories-US military
3364153364157104	Missile and space vehicle engines or propulsion parts and accessories-US nonmilitary
3364153364157107	Missile and space vehicle engines or propulsion parts and accessories-other customers
3364193364191311	Missile/space vehicle components, etc. – US nonmilitary
3364193364191413	Missile/space vehicle components, etc. – other customers
325120325120C1	Argon and hydrogen
33231M332313346	Weldments and fabricated steel plate for other purposes
332710332710T	Machine shops
33281M332812T	Metal coating, engraving (except jewellery and silverware), and allied services to manufacturers
33291N3329121	Aerospace type hydraulic fluid power valves
33291N3329123	Aerospace type pneumatic fluid power valves
33399N33399671	Aerospace type fluid power pumps and motors
334111334111D1	Other Computers, including Array and Other analog, hybrid, and special purpose
334111334111W	Electronic computers nsk., total
334111AO	Electronic computer manufacturing other miscellaneous receipts
334111IC	Electronic computer manufacturing inventory change
334118334118IC	Computer terminal manufacturing inventory change
334118334118W	Computer terminals, nsk., total
334118AO	Computer terminal manufacturing other miscellaneous receipts
33422033422014X	Other communication systems and equipment
3342203342202X	Broadcast, studio, and related electronic equipment
3342203342203X	Wireless networking equipment
334220334220W	Radio and TV broadcasting and wireless communications equipment, nsk

Commodity code	Commodity description
334220AO	Radio and television broadcasting and wireless communications equipment manufacturing other miscellaneous receipts
334220IC	Radio and television broadcasting and wireless communications equipment manufacturing inventory change
334290334290W	Other communications equipment, nsk
334290AO	Other communications equipment manufacturing other miscellaneous receipts
334290IC	Other communications equipment manufacturing inventory change
334413334413T	Semiconductor and related device manufacturing
334413AO	Semiconductor and related device manufacturing other miscellaneous receipts
334413IC	Semiconductor and related device manufacturing inventory change
334417334417T	Electronic connectors
334417AO	Electronic connector manufacturing other miscellaneous receipts
334417IC	Electronic connector manufacturing inventory change
334419334419AO	Electron tube manufacturing other miscellaneous receipts
334419334419IC	Electron tube manufacturing inventory change
334419334419T	Electron tubes and parts, excluding glass blanks
334419334419W	Other electronic component manufacturing
334419AO	Other electronic component manufacturing other miscellaneous receipts
334419IC	Other electronic component manufacturing inventory change
334511334511W	Search, detection, navigation, and guidance systems, nsk.
334511AO	Search, detection, navigation, guidance, aeronautical, and nautical system and instrument manufacturing other miscellaneous receipts
334511IC	Search, detection, navigation, guidance, aeronautical, and nautical system and instrument manufacturing inventory change
334513334513012X	General-purpose control system instruments (commonly called receiver-type), operating from standardized transmission signals
334513334513021F	Continuous process instruments (pneumatic systems, including all system-type control, display and computing instruments)
3345133345130256X	Pressure and draft measuring instruments
3345133345130267X	Flow and liquid level measuring instruments
33451333451302X	Temperature measuring instruments, Thermocouples, and Humidity Instruments
33451333451303X	Parts for process control instruments
334513AO	Instruments and related products manufacturing for measuring, displaying, and controlling industrial process variables other miscellaneous receipts
334513IC	Instruments and related products manufacturing for measuring, displaying, and controlling industrial process variables inventory change
334513RW	Instruments and related products manufacturing for measuring, displaying, and controlling industrial process variables repair work
334515334515T	Instruments to measure electricity
334515AO	Instrument manufacturing for measuring and testing electricity and electrical signals other miscellaneous receipts
334515IC	Instrument manufacturing for measuring and testing electricity and electrical signals inventory change
334515RW	Instrument manufacturing for measuring and testing electricity and electrical signals repair work
3345163345160X	Analytical and scientific instruments, except optical
334516AO	Analytical laboratory instrument manufacturing Other miscellaneous receipts
334516IC	Analytical laboratory instrument manufacturing Inventory change
334516RW	Analytical laboratory instrument manufacturing repair work
3345193345195A	Nuclear radiation detection and monitoring instruments
3345193345197C	Seismic instruments
334519334519W	Watches, clocks, parts, other measuring and controlling devices, nsk.
335991335991T	Carbon and graphite products
335991AO	Carbon and graphite product manufacturing Other miscellaneous receipts
335991IC	Carbon and graphite product manufacturing Inventory change
336413336413W	Aircraft parts and auxiliary equipment, nec., nsk. total
336413AO	Other aircraft parts and auxiliary equipment manufacturing Other miscellaneous receipts
336413IC	Other aircraft parts and auxiliary equipment manufacturing inventory change
336414336414A101	All other services on complete space vehicles for US govt. military customers

Commodity code	Commodity description
336414336414A104	All other services on complete space vehicles for other customers
336414336414AY	All other services on complete space vehicles, nsk.
336414336414W	Guided missile and space vehicle manufacturing, nsk.
336414AO	Guided missile and space vehicle manufacturing Other miscellaneous receipts
336414IC	Guided missile and space vehicle manufacturing inventory change
3364153364157Y	Missile and space vehicle engines or propulsion parts and accessories, nsk.
336415336415W	Space propulsion units and parts, nsk.
336415AO	Guided missile and space vehicle propulsion unit and propulsion unit parts manufacturing other miscellaneous receipts
336415IC	Guided missile and space vehicle propulsion unit and propulsion unit parts manufacturing inventory change
336419336419W	Other guided missile and space vehicle parts and auxiliary equipment, nsk.
336419AO	Other guided missile and space vehicle parts and auxiliary equipment manufacturing other miscellaneous receipts
336419IC	Other guided missile and space vehicle parts and auxiliary equipment manufacturing inventory change
3391133391136Y	Personal industrial and nonindustrial safety equipment and clothing, nsk.
5241XX2810	Aircraft Insurance (property and casualty)
541330CM	Construction management services
541360T	Geophysical surveying and mapping services
541370T	Surveying and mapping (except geophysical) services
541380T	Testing laboratories
541512T	Computer systems design services
541519T	Other computer related services
541611T	Administrative management and general management consulting services
541690T	Other scientific and technical consulting services
54170AFS3364	For sale auxiliary scientific research and development (taxable) aerospace product and parts manufacturing
54170AFSM	For sale auxiliary scientific research and development (taxable) all other manufacturing industries
54170AFSNM	For sale auxiliary scientific research and development (taxable) all other non-manufacturing industries
54170NEFS3364	For sale academic scientific research and development (tax exempt) aerospace product and parts manufacturing
54170NEFS5417	For sale academic scientific research and development (tax exempt) scientific R&D services
54170NEFSFED	For sale academic scientific research and development (tax exempt), federal funded
54170NEFSM	For sale academic scientific research and development (tax exempt) all other manufacturing
54170NEFSNM	For sale academic scientific research and development (tax exempt) all other non-manufacturing
54170NFS3364	For sale scientific research and development (tax exempt) aerospace product and parts manufacturing
54170NFS5417	For sale scientific research and development (tax exempt) scientific R&D services
54170NFSM	For sale scientific research and development (tax exempt) all other manufacturing
54170NFSNM	For sale scientific research and development (tax exempt) all other non-manufacturing
54170NFSNPFED	For sale scientific research and development (tax exempt) all other non-profit industries, federal funded
54170NOAFGD	Own account scientific research and development (tax exempt) federal government defence
54170NOAFGND	Own account scientific research and development (tax exempt) federal government non-defence
54170PFS3364	For sale scientific research and development (taxable) aerospace product and parts manufacturing
54170PFS5417	For sale scientific research and development (taxable) scientific R&D services
54170PFSM	For sale scientific research and development (taxable) all other manufacturing industries
54170PFSNM	For sale scientific research and development (taxable) all other non-manufacturing industries
54170POA3364	Own account scientific research and development (taxable) aerospace product and parts manufacturing
54170POA5417	Own account scientific research and development (taxable) scientific R&D services
54170POAM	Own account scientific research and development (taxable) all other manufacturing
54170POANM	Own account scientific research and development (taxable) all other non-manufacturing
5418XX11	Radio, television, and cable advertising
61123N01	Expenses of colleges, universities, professional schools, and junior college education services (tax exempt)
61123N02	Expenses of colleges, univ., prof. schools, junior college incidental to education activities (tax exempt)
61123N03	Expenses of colleges, universities, professional schools, and junior college research and development (tax exempt)
61123NR01	Tax exempt receipts from sales of colleges, universities, professional schools, and junior colleges education services (tax exempt)
61123NR02	Tax exempt receipts from sales of colleges, univ., prof. schools, jr colleges incidental to educ. Activities (tax exempt)
61123P01	Colleges, universities, professional schools, and junior colleges higher education services (taxable)

Commodity code	Commodity description
61123P02	Sales and svcs, colleges, univ., prof. Schools, jr. colleges incidental to education activities (taxable)
71210N1	Cultural institutions -– expenses
71210NRT	Cultural institutions -– tax exempt receipts
71210PT	Cultural institutions (taxable)
99FD02T	Federal defence government services
99FN02T	Federal non-defence government services
99S392T	S&l other general government services

Note: More information on the US Space Economy Satellite Account can be found in Highfill, Jouard and Franks (2020[2]), "Preliminary estimates of the U.S. space economy, 2012–2018", https://apps.bea.gov/scb/2020/12-december/1220-space-economy.htm.

Annex 2.B. European classification codes for selected space products and services

The following table provides some concordance for selected space products and services identified in European and international classifications at different digit levels. Relevant frameworks include the Statistical Classification of Economic Activities in the European Community (NACE), as well as the Statistical Classification of Products by Activity in the European Union, Version 2.1 (CPA). CPA is the European version of the CPC (Central Product Classifications) of the United Nations. It is more detailed, it has a slightly different structuring which corresponds at all levels to that of NACE. In addition, PRODCOM statistics aim at providing a full picture at European Union level of developments in industrial production for a given product or for an industry in a comparable manner across countries. PRODCOM uses an eight-digit numerical code, the first six digits of which are, in general, identical to those of the CPA code. The headings of the PRODCOM list are also derived from the international Harmonized System (HS) or the Combined Nomenclature (CN), which enables comparisons to be made between production statistics and foreign trade statistics.

Annex Table 2.B.1. Concordance table for selected space products and services

NACE	ISIC	CPA 2.1	Description	PRODCOM 2014	HS/CN
Manufacturing					
30.3 Manufacture of air and spacecraft and related machinery	3030	30.30.13	Reaction engines, excluding turbojets	30.30.13.00	
		30.30.40	Spacecraft (including satellites) and spacecraft launch vehicles	30.30.40.00 (Spacecraft, satellites and launch vehicles, for civil use)	88026010
					8826090
		30.30.50	Other parts of aircraft and spacecraft	30.30.50.50 (Undercarriages and parts thereof for dirigibles, gliders, hang gliders and other non-powered aircraft, helicopters, aeroplanes, spacecraft and spacecraft launch vehicles, for civil use)	880320
				30.30.50.90 (Parts for all types of aircraft excluding propellers, rotors, under carriages, for civil use)	8839010
					8839020
					8839030
33.16 Repair and maintenance of aircraft and spacecraft	3315	33.16.10	Repair and maintenance of aircraft and spacecraft	33.16.10.00 (Repair and maintenance of civil aircraft and aircraft engines)	
25.62 Machining	2562	25.62.10	Turning services of metal parts	25.62.10.07 (Turned metal parts for aircraft, spacecraft and satellites)	
26.3 Manufacture of communications equipment	2630	26.30.22	Telephones for cellular networks or for other wireless networks	26.30.22.00 (Telephones for cellular networks or for other wireless networks)	851712
		26.30.23	Other telephone sets and apparatus for transmission or reception of voice, images or other data, including apparatus for communication in a wired or wireless network (such as a local or wide area network)	26.30.23.10 (base stations)	851761
				26.30.23.20 (Machines for the reception, conversion and transmission or regeneration of voice, images or other data, including switching and routing apparatus)	851762
26.51 Manufacture of instruments and appliances for	2651	26.51.11	Direction-finding compasses; other navigational instruments and appliances	26.51.11.50 (Instruments and appliances for aeronautical or space navigation (excluding compasses)	90142020
					90142080

NACE	ISIC	CPA 2.1	Description	PRODCOM 2014	HS/CN
measuring, testing and navigation		26.51.12	Rangefinders, theodolites and tachymetres (tachometers); other surveying, hydrographic, oceanographic, hydrological, meteorological or geophysical instruments and appliances	26.51.12.15 (Electronic rangefinders, theodolites, tacheometers and photogrammetrical instruments and appliances)	90151010
				26.51.12.35 (Electronic instruments and apparatus for meteorological, hydrological and geophysical purposes (excluding compasses)	90152010
				26.51.12.39 (Other electronic instruments)	90154010
				26.51.12.70 (Surveying (including photogrammetrical surveying), hydrographic, oceanographic, hydrological, meteorological or geophysical instruments and appliances (excluding levels and compasses), non-electronic; rangefinders, non-electronic)	90151090, 90152090, 90154090, 90158091, 90158093, 90158099
		26.51.20	Radar apparatus and radio navigational aid apparatus	26.51.20.20	852610
				26.51.20.50	85269120
					85269180
		26.51.81	Parts of radar apparatus and radio navigational aid apparatus	26.51.81.00	
26.52 Watches and clocks	2652	26.52.13	Instrument panel clocks and clocks of a similar type for vehicles	26.52.13.00 (Instrument panel clocks and clocks of a similar type for vehicles, aircraft, spacecraft or vessels (including vehicle chronographs))	9104
26.70 Manufacture of optical instruments and photographic equipment	2670	26.70.21	Sheets and plates of polarising material; lenses, prisms, mirrors and other optical elements (except of glass not optically worked), whether or not mounted, other than for cameras, projectors or photographic enlargers or reducers	26.70.21.53 (Prisms, mirrors and other optical elements, n.e.c.)	900190
				26.70.21.55 (Mounted lenses, prisms, mirrors, etc., of any material, n.e.c.)	900290
				26.70.21.70 (Mounted objective lenses of any material (excluding for cameras, projectors or photographic enlargers or reducers))	900219
				26.70.21.80 (Unmounted sheets and plates of polarising material; mounted filters of any material)	900120 900220
		26.70.22	Binoculars, monoculars and other optical telescopes; other astronomical instruments; optical microscopes	26.70.22.50 (Instruments (excluding binoculars) such as optical telescopes)	900580
		26.70.23	Liquid crystal devices; lasers, except laser diodes; other optical appliances and instruments n.e.c.	26.70.23.30 (Lasers (excluding laser diodes, machines and appliances incorporating lasers)	901320
Selected services					
43.21 Specialised construction activities	4321	43.21.10	Electrical installation works (including installation of satellite dishes)	n.a.	
51.22 Space transport	5120	51.22.11	Space transport services of passengers	n.a.	
		51.22.12	Space transport services of freight	n.a.	
	6512	65.12.33	Other aircraft insurance services	n.a.	

NACE	ISIC	CPA 2.1	Description	PRODCOM 2014	HS/CN
65.12 Non-life insurance (includes motor, marine, aviation and transport insurance)			(including space transport)		
		65.12.36	Freight insurance services (including space transport)	n.a.	
71.1 Engineering activities and related technical consultancy: - geophysical, geologic and seismic surveying - geodetic surveying activities - land and boundary surveying activities - hydrologic surveying activities - subsurface surveying activities - cartographic and spatial information activities	7110	71.12.34	Surface surveying services (includes surveying by satellites	n.a.	
		71.12.35	Map-making services (includes satellite surveying)	n.a.	
74.90 Other professional, scientific and technical activities n.e.c., including - weather forecasting activities - security consulting - agronomy consulting - environmental consulting - other technical consulting	7490	74.90.13	Environmental consulting services	n.a.	
		74.90.14	Weather forecasting and meteorological services	n.a.	
		74.90.19	Other scientific and technical consulting services n.e.c.	n.a.	
61.3 Satellite telecommunications activities	6130	61.30.10	Satellite telecommunications services, except home programme distribution services via satellite	n.a.	
		61.30.20	Home programme distribution services via satellite	n.a.	

Note: n.a.= Not applicable.

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3 Monitoring the evolving cast of space actors

Governments need to keep track of how, where and by whom space activities are being conducted in order to tailor public policy accordingly. This chapter provides a comprehensive overview of the actors performing space activities with definitions for better distinguishing between actors and improving international data comparability.

Introduction

In the first three decades of the space age between the late 1950s and the 1980s, relatively few actors were involved in national space programmes. Generally, one or two public research organisations and sometimes a limited number of private contractors (mainly large aeronautics and/or defence conglomerates) were involved. Activities were government funded, led as part of what might today be called mission-oriented policies, and the “client” base was composed of defence or scientific communities, rarely society at large (Undseth, Jolly and Olivari, 2021[1]). While certain aspects of this situation continue to this day, space industrial ecosystems have expanded and diversified both on the supply and demand side.

Today, the space economies of countries with advanced programmes revolve around very large and complex ecosystems of actors that can be challenging to assess. It is particularly difficult to keep track of downstream activities relying on the exploitation of satellite data and signals.

Why does this matter? Space activities play an increasingly important role for the functioning of our modern societies, with several industry segments providing services crucial to critical infrastructures, such as defence or telecommunications. Tracking the organisations taking part in space economy value chains is therefore increasingly useful to support national security, economic and wellbeing objectives. Furthermore, the space economy is increasingly considered as a source of economic growth – albeit one that is still in need of government intervention and support. Barriers to entry in space activities are still substantial as they are associated with high fixed costs and specific conditions (i.e. highly uncertain outcomes with returns that are difficult to appropriate and with long time lags to reap benefits) that reduce private sector incentives for investing in research and development (OECD, 2002[2]).

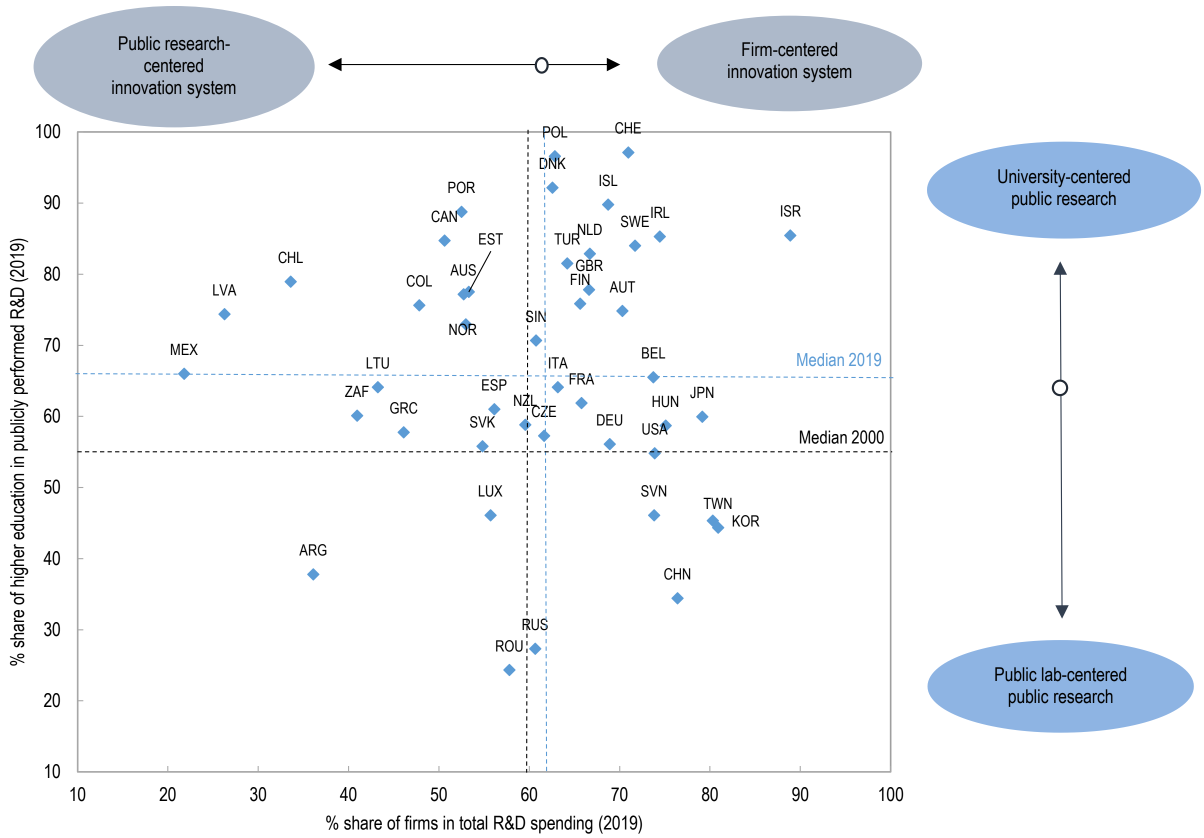
Governments therefore need to keep track of how, where and by whom space activities are being conducted in order to tailor public policy accordingly. In order to assist governments in their efforts to understand space activities, this chapter aims to provide a comprehensive overview of the actors, definitions for better distinguishing between actors and improving international data comparability and, finally, explain different ways in which this information might be collected. But before identifying the actors, some background is needed on the national innovation ecosystems in which they operate.

National innovation systems and the space ecosystem

Space policies are firmly grounded in national innovation frameworks where different actors, policies and governing institutions constitute a multi-layered and interdependent system. The effectiveness of policy actions depends in part on how they interact with other initiatives and policy instruments (OECD, 2010[3]). R&D performed by government is likely to differ in its application and diffusion from R&D performed by businesses enterprises. Some argue that more decentralised ecosystems, i.e. with more R&D performed by business enterprises and higher education institutions (HEIs), are more innovative (Weinzierl, 2018[4]), but government-led, mission-oriented, policy also has its champions (Robinson and Mazzucato, 2019[5]).

Figure 3.1 gives an overview of innovation systems in selected OECD countries and partner economies in 2019 (covering the entire R&D domain, not only space). More specifically, the figure tracks the shares of gross domestic R&D expenditure (GERD) by the business enterprise sector and compares it to the share of expenditure in the government and higher education sectors performed by HEIs. In a majority of OECD member countries and partner economies, business firms perform more than half of total domestic R&D and HEIs account for more than half of publicly performed R&D (OECD, 2021[6]). Median values for 2000 and 2019 indicate a trend towards more R&D performed by non-government actors in the private sector or in HEIs.

Figure 3.1 Archetypes for national innovation systems (beyond the space sector)



Notes: Data for Australia, South Africa and Switzerland from 2017. Data for Chile and Singapore from 2018.
Source: OECD (2021[6]), *Main Science and Technology Indicators, Volume 2021 Issue 1*, https://doi.org/10.1787/eea67efc-en.

As will be shown in the following sections, space activities remain mostly government led. Government research organisations continue to play an important role both in the funding of and, occasionally, in actually conducting space activities. However, there are many national and sectoral differences.

Role of the government sector in the space economy

The government sector plays a key role in the space economy as investor, developer, owner, operator, regulator and customer. National agencies, research centres and laboratories also perform space R&D and, in some cases, have a manufacturing role (e.g. India, Korea). The bulk of their funding tends to be public, but they may also receive private financing via contracts and licensing arrangements etc.

The international classification of actors involved in R&D, as described in the *Frascati Manual*, is often used to gather comparable data concerning the R&D activities of governments. As described in Chapter 4, these definitions should form the baseline for many space industry surveys. According to the *Frascati Manual*, the government sector includes:

- all units of central (federal), regional (state) or local (municipal) government, (except those units that provide higher education services or fit the description of higher education institutions)
- all non-market non-profit institutions that are controlled by government units, (which are not part of the higher education sector).

Space activities are carried out in many different parts of the government sector (e.g. defence, communication, transport, environment, etc.) and at different levels of government (central, provincial and municipal). Typical government sector space organisations include space agencies, research institutes, laboratories and ground-testing facilities. They often belong to the portfolios of ministries of industry, innovation and economic affairs (e.g. Germany, Norway) or science and research (e.g. Italy, Japan). Table 3.1 provides an overview of selected space agencies and offices in OECD countries and partner economies as well as the government ministry or department responsible for them.

Table 3.1. Selected space agencies in OECD member countries and partner economies

Economy/region	Organisation name	Responsible department/ministry	Year of creation
Australia	Australian Space Agency (ASA)	Department of Industry, Science, Energy and Resources	2018
Austria	Austrian Aeronautics and Space Agency (ALR)	Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) and the Federal Ministry for Digital and Economic Affairs (BMDW)	1972
Brazil	Brazilian Space Agency (AEB)	Ministry of Science, Technology and Innovation	1994
Canada	Canadian Space Agency (CSA)	Innovation, Science and Economic Development Canada (ISED)	1989
People’s Republic of China	China National Space Administration (CNSA)	Ministry of Industry and Information Technology (MIIT)	1993
Costa Rica	Costa Rican Space Agency (AEC)	Non-state public entity	2021
Europe	European Space Agency (ESA)	Intergovernmental organisation	1975
France	French Space Agency (CNES)	Ministry of the Economy, Finance and the Recovery	1961
Germany	German Aerospace Center (DLR)	Federal Ministry of Economic Affairs and Climate Action	1969
India	Indian Space Research Organisation (ISRO)	Department of Space	1969
Israel	Israeli Space Agency (ISA)	Ministry of Science and Technology	1983
Italy	Italian Space Agency (ASI)	Ministry of University and Research	1988
Japan	Japan Aerospace Exploration Agency (JAXA)	Ministry of Education, Culture, Sports, Science and Technology (MEXT); Cabinet Office	2003
Korea	Korea Aerospace Research Institute (KARI)	Ministry of Science and ICT	1989
Luxembourg	Luxembourg Space Agency (LSA)	Ministry of the Economy	2019
Malaysia	Malaysian Space Agency (MYSA)	Ministry of Science, Technology & Innovation (MOSTI)	2002
Mexico	Mexican Space Agency (AEM)	Ministry of Communications and Transportation	2010
Netherlands	Netherlands Space Office (NSO)	Ministry of Economic Affairs and Climate Policy, Ministry of Education, Culture and Science, Ministry of Infrastructure and Water Management and the Netherlands Organization for Scientific Research (NWO)	2009
New Zealand	New Zealand Space Agency	Ministry of Business, Innovation & Employment	2016
Norway	Norwegian Space Agency (NOSA)	Ministry of Trade, Industry and Fisheries	1987
Poland	Polish Space Agency (POLSA)	Ministry of Economic Development and Technology	2014
Portugal	Portugal Space (PTSPACE)	Private, non-profit	2019
Romania	Romanian Space Agency (ROSA)	Ministry of Research and Innovation	1991
Russian Federation	State Space Corporation Roscosmos	State corporation	1992
South Africa	South African Space Agency (SANSA)	Department of Science and Innovation	2010
Spain	National Institute of Aerospace Technology (INTA)	Ministry of Defence	1942
Sweden	Swedish National Space Agency	Ministry of Education and Research	1972

Economy/region	Organisation name	Responsible department/ministry	Year of creation
	(SNSA)		
Switzerland	Swiss Space Office (SSO)	State Secretariat for Education, Research and Innovation (SERI)	1998
Turkey	Turkish Space Agency (TUA)	Ministry of Industry and Technology	2018
United Kingdom	UK Space Agency (UKSA)	Department for Business, Energy & Industrial Strategy	2010
United States	National Aeronautics and Space Administration (NASA)	Independent government agency	1958

Government agencies and ministries in charge of space perform important tasks associated with policy formulation, procurement and infrastructure management, among others. In addition, some agencies also carry out R&D (e.g. the CNES in France, the DLR in Germany) and/or manufacturing (the ISRO in India and the KARI in Korea). Some of these organisations focus solely on space activities but more often they also specialise in aeronautics (e.g. NASA in the United States, the DLR in Germany, and the KARI in Korea). In Germany, there are two more or less independently run facilities under the roof of the DLR: The German Space Agency at the DLR and DLR R&D. The number of space agencies has increased significantly in recent years signalling a growing need for co-ordinating national space activities and/or formulating integrated space policies.

While it is relatively easy to keep track of larger space programme activities, it can be surprisingly difficult to comprehensively outline and understand all space activities conducted by the government sector even at the central level. Space activities are carried out in many parts of government sectors, not just those related to defence, communications, land cover management, meteorology and the environment. The Norwegian government has identified a total of 14 ministries that use satellite services, consume satellite services as an intermediate good (e.g. transport, agriculture, fisheries, communications) and/or are implicated in formulating space-related policy (Norwegian Ministry of Trade and Industry, 2012[7]). In the United States, US government organisations such as the Department of Defense, the National Oceanic and Atmospheric Administration (NOAA) and United States Geological Survey (USGS) have important space-related portfolios where they are, in many cases, both providers and users of space services. In Australia, the Space Co-ordination Committee (SCC) maps and co-ordinates all government activities in civil space and ensures that the country has the capabilities it needs both now and in the future. In 2022, the committee had some 14 different members, including four ministries and the Cabinet Office A State of the Space report has been produced at regular intervals since 2014 to document national and international government activities (Australian Space Agency, 2020[8]).

Other important space-related government sector organisations include research agencies, innovation agencies and fiscal authorities. Public investment banks may play an important role in supporting entrepreneurs and small and medium-sized enterprises through the provision of grants, loans and tax credits. Provincial and municipal authorities may also act as users (of mainly satellite services) or provide support to enterprises and installations. One example is Space Florida, a mainly publicly funded organisation promoting space activities in Florida with operating revenues of more than USD 67 million in 2020 (Space Florida, 2021[9]). The Canadian space industry survey keeps track of municipal and provincial governments as part of the domestic market for space products and services. The non-federal government proportion of domestic revenues is small, accounting for just 0.64% of the total in 2019 (CSA, 2022[10]).

Government R&D performers

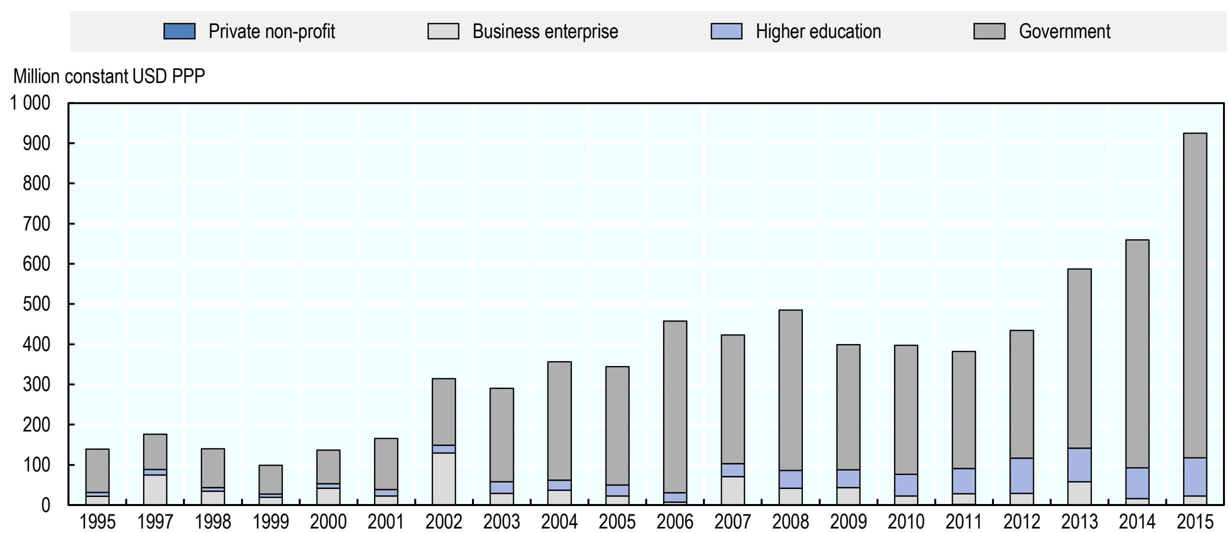
Government research institutes and laboratories have traditionally carried out the bulk of public space-related R&D in OECD countries. Some research institutes are entirely dedicated to space activities. The most prominent example is perhaps the Jet Propulsion Laboratory (JPL) in the United States, which is funded by NASA but operated by the California Institute of Technology. JPL received USD 2.8 billion in NASA awards (contracts and grants) in 2020 which equates to around 14% of NASA's total procurement budget (NASA, 2021[11]). More commonly, research institutes also engage in other research activities (e.g.

energy, transport, aerospace, like the DLR R&D in Germany) and often defence-related research activities (e.g. the DARPA in the United States, the ONERA in France, DLR R&D in Germany, and INTA in Spain). In Korea, the space industry sector survey for the year 2019 identified 34 research institutes with varying levels of budgeted engagement in space-related activities (Korean Ministry of Science and ICT, 2020[12]).

In official statistics, the recording of R&D expenditure can be broken down according to socio-economic objectives (SEOs) and by performing actor. One of these SEOs is "the exploration and exploitation of space". Few OECD countries collect this type of data, but interesting lessons can be drawn from those that do. Figure 3.2 shows Korea's gross domestic expenditure for space R&D, with the time series starting just after the creation of the Korean space programme in the early 1990s. The data show the continued strong reliance on government organisations in the Korean space economy.

Figure 3.2. Gross domestic expenditure on space R&D by sector in Korea

Measured in constant 2015 dollars PPP, latest available year



Source: OECD (2021[13]), "Research and Development Statistics: Gross domestic expenditure on R&D by sector of performance and socio-economic objective", *OECD Science, Technology and R&D Statistics* (database), https://doi.org/10.1787/data-00188-en (accessed on 15 December 2021).

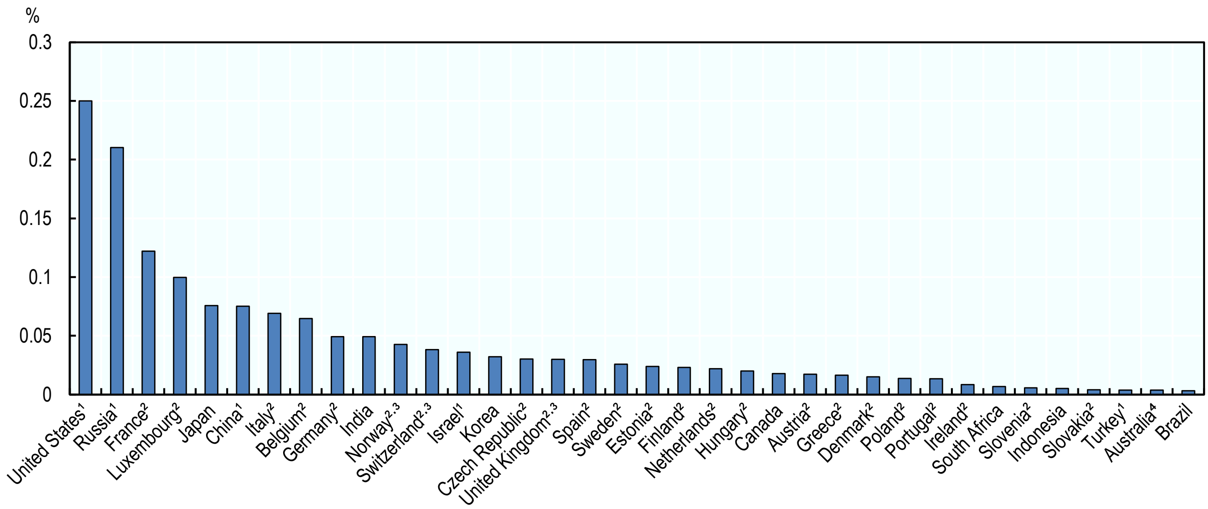
Since 2015, Korea has taken steps to move away from this government-led model, seeking to transfer initiative and responsibility to the private sector through formal partnerships and by procuring services (Undseth, Jolly and Olivari, 2021[1]).

The role of government funding

In terms of government funding activities, the OECD keeps track of institutional space budgets (comprising civil and military programmes, where data are available) (Figure 3.3) and civil space budget allocations for R&D through a database maintained by the OECD Space Forum.

Figure 3.3. Government space budget allocations for selected countries and economies

Measured as a share of GDP in 2020



1. Conservative estimates, including defence programmes. 2. Includes contributions to the European Space Agency and Eumetsat. 3. Includes contributions to one or several EU space programmes (e.g. Copernicus, Galileo/EGNOS). 4. Includes only civil R&D.
Notes: GDP is a measurement of the market value of all final goods and services produced in the economy and it does not include the value of intermediate inputs. Budgets include data for civil and defence programmes, when available.
Sources: Government budget sources and OECD databases.

Box 3.1. Methodological note on government space budgets

This indicator includes government budget allocations to national and international civil and military space activities, subject to data availability. Government grants and procurement account for the lion's share of institutional space budgets. They are typically channelled through national space agencies and international space organisations (e.g. NASA or ESA), but increasingly through other actors as well, such as the EU Horizon 2020 R&D programme or the European GNSS Agency (GSA). Data are based on government budget estimates for the latest available year, and actual expenditure for previous years, as identified in national accounts. Government space budgets are spent on both final goods and intermediate inputs.

International comparisons of institutional budgets for space activities can be affected by many factors, in particular exchange rate issues and data sources. The last years have seen many exchange rate fluctuations, making comparisons of national budgets in US dollars (USD) more difficult. Furthermore, differences in purchasing power parity (PPP) are not accounted for. However, converting budgets to PPP-adjusted USD further complicates matters, as a substantial share of space products and services are internationally traded. Therefore, comparing budgets using the ratio budget/gross domestic product (GDP) based on national currencies still provides the most reliable snapshot of the situation, despite other methodological caveats (e.g. impacts of GDP growth or contraction; potential overstated economic effects of budgets on GDP).

Regular industry surveys of public and private space actors inquiring on the sources of funding for space activities show that government funding is an important source of income for other space actors. The role of governments as customer to space business enterprises seems to be particularly important for upstream segment companies (those operating in space manufacturing and launch activities, see Chapter 2 for details). In consequence, it is quite common for industry reports to double-count government spending when presenting space economy data, adding up commercial companies' revenues and annual government space budgets (the issues of double-counting and how to avoid them will be discussed in Chapter 4).

The significance of government contracts for the space industry can be tracked in industry surveys. An industry survey conducted by the Canadian Space Agency found that the government sector accounted for 11% of total revenues (domestic sales and exports) in the Canadian space sector in 2019. But the share differed considerably between upstream and downstream segments. The results suggest 38% of the total revenue of the upstream segment and 6% of total revenue in the downstream segment was attributable to the government sector (CSA, 2022[9]).

This finding is found in other industry surveys as well. In Europe, public organisations (European Space Agency, European Union, national agencies, etc.) accounted for 71% of sales in the upstream segment in 2019 (Eurospace, 2020[13]). In Korea, government ministries and other public institutions accounted for 62% of private sector total domestic revenues and 76% of the domestic upstream segment revenues in 2019 (Korean Ministry of Science and ICT, 2020[11]). In Japan, government and public organisations accounted for 71% of domestic demand (mainly upstream segment) in 2019 (SJAC, 2021[14]). Meanwhile, the latest space industry survey in the United Kingdom found that domestic and international public sector actors accounted for 18.7% of space sector income when combining both upstream and downstream activities (know.space, 2021[15]). Some of these differences in estimates reflect differing definitions and approaches to measuring the size of the space economy, as already discussed in Chapter 2.

Role of the higher education sector in the space economy

Higher education institutions play a key role in space R&D in many OECD member countries and partner economies. They often supply R&D services to space-related administrations. They are a source of innovation, knowledge diffusion and technological transfer for the sector, carrying out basic and applied research as well as publishing and patenting activities. Furthermore, many space economy start-ups originate in the higher education sector (Breschi et al., 2019[16]).

According to the *Frascati Manual*, the higher education sector includes:

- universities, colleges and other institutions providing formal tertiary education
- research institutes, centres, experimental stations and clinics that have their R&D under direct control of or are administered by tertiary education institutions.

It is worth to note that research institutes and centres that sell their output for an economically significant price and for which higher education is not a core activity are considered business enterprises.

It can be more challenging to outline and understand space activities in the higher education sector than in the government sector. This is because space-related academic disciplines (e.g. astrophysics, space engineering and remote sensing) are often too small to be identified in university budget accounts and annual reports. In general, there is a lack of data available on enrolment and graduation in space-related scientific disciplines. Differing practices among countries in defining what constitutes the government sector, research institutes and higher education institutions also make international comparisons difficult. The most detailed categories in the international statistical nomenclature for education and training, the ISCED-F (UNESCO/UIS, 2015[18]) and the Fields of Research and Development for the higher education sector (FORD) (OECD, 2015[19]), are also too aggregated to include space-related disciplines.

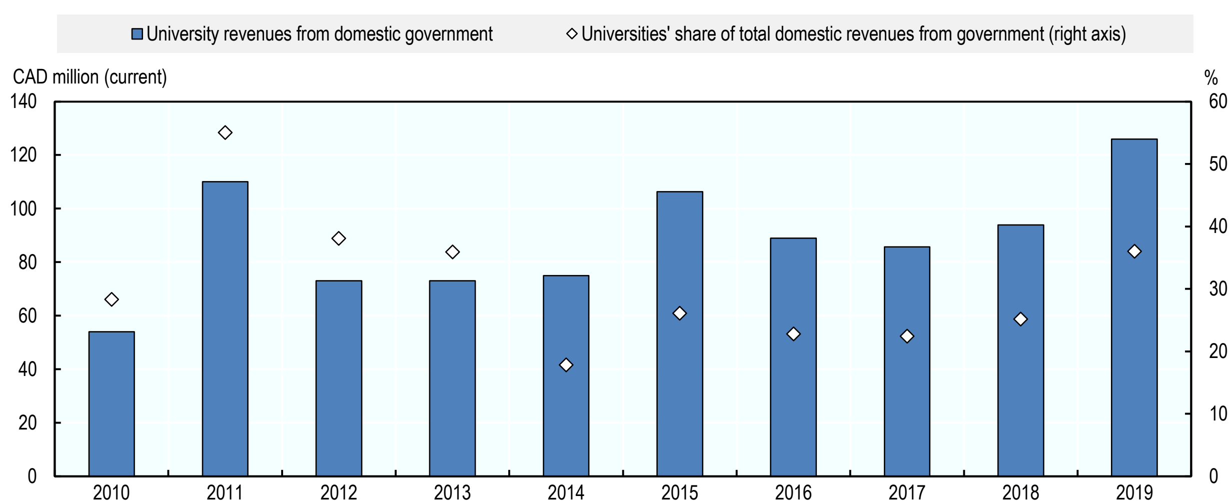
However, other data sources exist that can help outline and understand higher education organisations according to their purpose, including:

- national higher education statistics (education and training, and fields of research)
- industry surveys
- grants and contract information.

Some national nomenclatures provide more granular categories than the international classifications. These codes have the benefit of being part of the national statistical system and therefore enable the production of statistics that are comparable with other fields of research. Examples include the US Classification of Instructional Programmes (CIP 2000). Here, astronomy, astrophysics and atmospheric sciences have separate codes whereas in other disciplines space is coupled with aerospace (e.g. aerospace engineering, aerospace medicine) (US National Center for Education Statistics, 2002[20]). The 2008 Australian and New Zealand Standard Research Classification (ANZSRC) (Australian Bureau of Statistics, 2008[21]), which is aligned with the FORD nomenclature suggested by the *Frascati Manual*, includes separate engineering codes for "satellite, space vehicle and missile design and testing" (090108), "navigation and position fixing" (090904) and "photogrammetry and remote sensing" (090905); a code for "satellite communications" (100508); and an extensive code selection in natural sciences, e.g. "astrobiology" (020101). The UK Higher Education Classification of Subjects (HECoS) have quite a number of relevant codes, including "space technology" (100116), "satellite engineering" (100118), "space science" (101102), "remote sensing" (101056), and "astrophysics" (100415 (HESA, 2021[22]).

Figure 3.4. Canadian universities and research centres' space-related revenues from the government sector

Space-related revenue flows from domestic government and organisations' share of total space-related domestic revenues from government



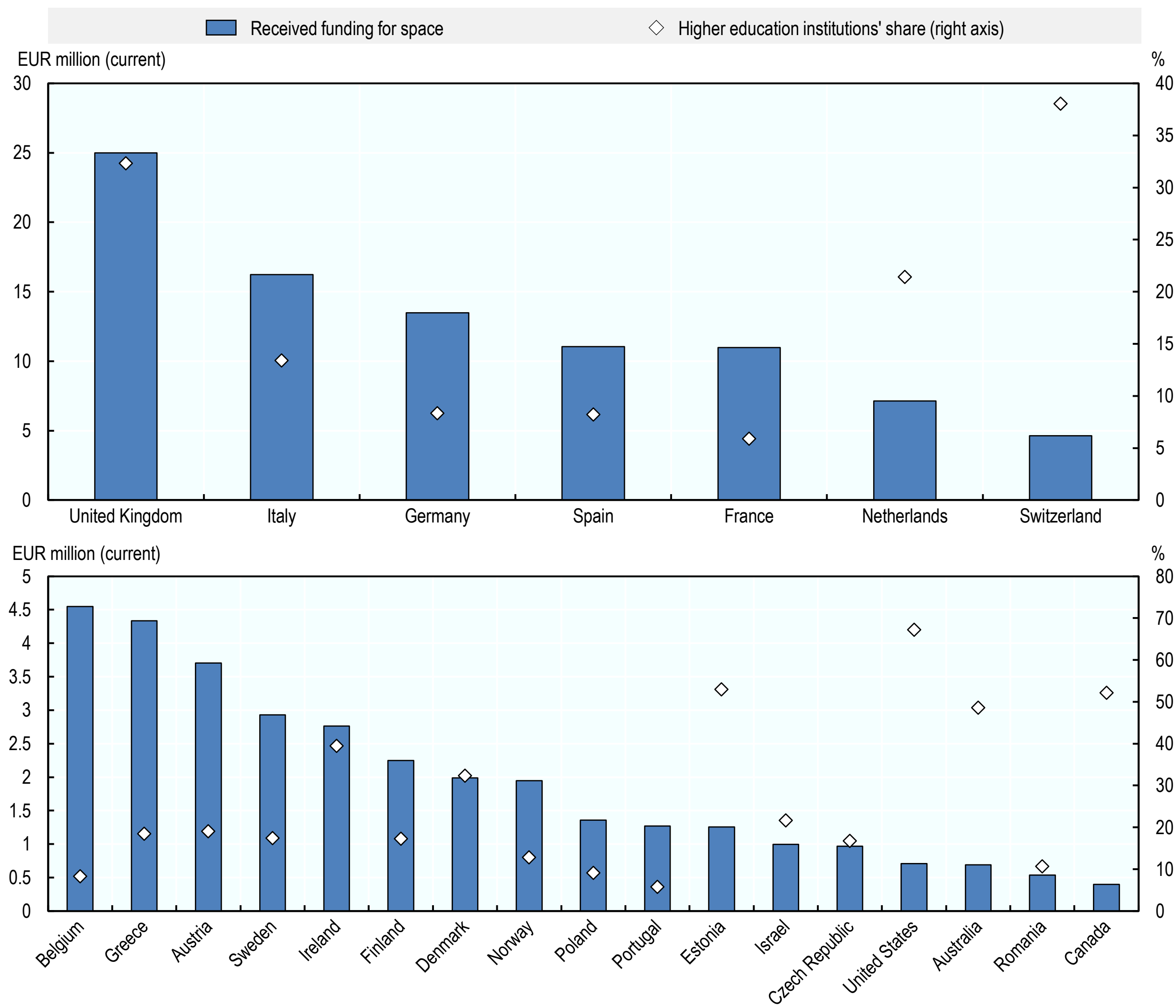
Source: Canadian Space Agency (2022[9]), "The state of the Canadian space sector 2019" and equivalent reports for the years 2010-20, https://www.asc-csa.gc.ca/eng/publications/2020-state-canadian-space-sector-facts-figures-2019.asp#results.

Dedicated surveys can also be a useful tool for gathering information on space activities in higher education institutions. Both Korea and Canada specifically address higher education institutions in their annual space sector surveys. The Korean survey distinguishes between research institutes and universities and includes detailed data on funding, areas of research and employment. In the Canadian State of the Space Sector survey, which has been running since 1996, the revenue flows of universities and research centres have been included in the summary report since the reporting year 2010. In 2019, universities and research centres contributed 2.7% (CAD 150 million) to total Canadian space revenues and 22% to employment

(CSA, 2022[9]). As a group, universities and research centres accounted for 36% of total domestic revenues generated by transfers from federal, provincial and municipal government in Canada (Figure 3.4).

Figure 3.5. Space-related grants to higher education institutes under the European Union's Horizon 2020 space programme

Received space-related grants and institutions' share of total country space-related grants. Reporting period between 1 January 2014 and 4 October 2020



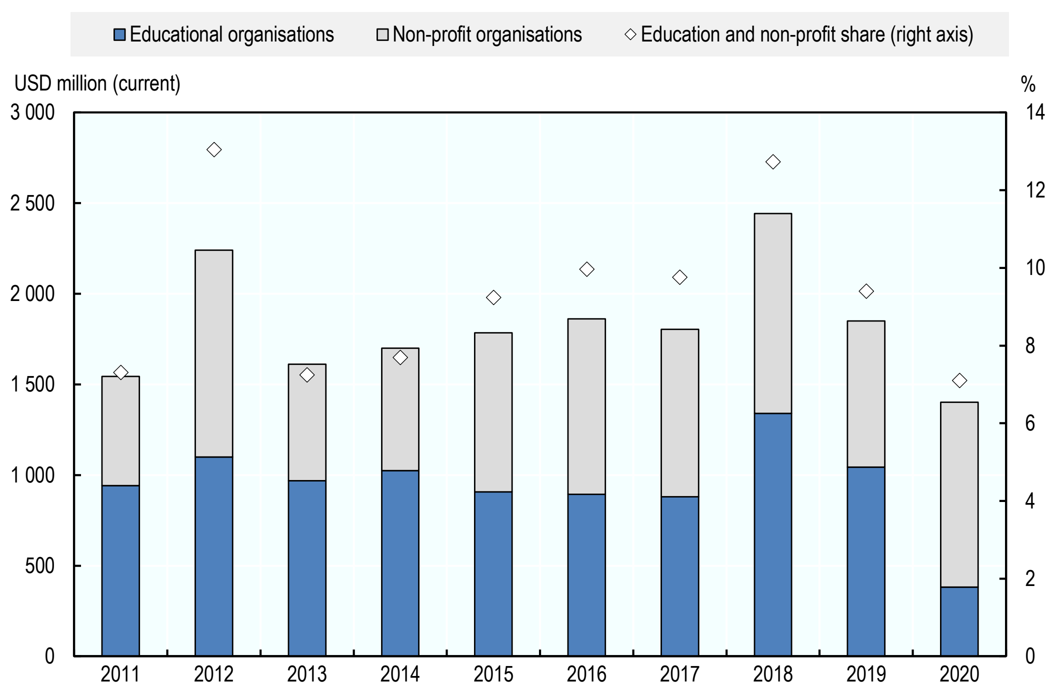
Notes: Horizon 2020 institution categories do not correspond to the institution categories in the *Frascati Manual*. In the *Frascati Manual*, research centres are mainly categorised under "Higher Education" or "Government sector". The figure was split in two to allow a maximum of countries to appear clearly.
Source: French Ministry of Research and Education (2021[23]), "Participations dans les contrats signés du programme-cadre pour la recherche et l'innovation (H2020) de la Commission européenne", https://data.enseignementsup-recherche.gouv.fr/pages/home/.

The evaluation of R&D grants and contracts is a third way to keep track of the space activities of universities and other higher education organisations. They participate in space-related programmes at the national level, mainly administered by national space agencies and research agencies. In addition, there are international programmes including in particular European Space Agency (ESA) activities and European Union (EU) research programmes.

In Horizon 2020, the EU's research framework programme for the period 2014-20, some EUR 1.25 billion was allocated to space research up to October 2020 (French Ministry of Research and Higher Education, 2021[23]). Figure 3.5 shows the grants accorded to HEIs in selected countries, as well as HEI's share of total country grants. There are substantial national differences in the participation patterns of HEIs. For example, universities in Switzerland, the United Kingdom and the Netherlands accounted for 38%, 32% and 21% of total received country grants, respectively. HEIs in comparable countries received less compared to other institutional sectors, such as business enterprises, (e.g. France (6%), Spain and Germany (both 8%). Figure 3.7 provides a similar breakdown for business enterprises.

Figure 3.6. NASA procurement awards to US educational and non-profit organisations

Awards as a share of total NASA procurement



Note: NASA defines "procurement awards" to include contracts, grants, cooperation agreements and purchase/delivery orders.
Source: NASA (2021[10]), "Annual procurement report: Fiscal year 2020" and equivalent reports for previous years, https://www.nasa.gov/sites/default/files/atoms/files/annual_procurement_report_fy20.pdf.

This type of statistic needs to be used and interpreted with care. The participation rates of specific actor groups can be explained by different factors including the maturity and specialisation of the domestic industry and the subject and design of calls for participation, for example. Also, differences in the statistical treatment of research centres (e.g. German Helmholtz centres based at universities) may skew results and complicate international comparisons. With these caveats in mind, these data can still shed more light on the role played by HEIs in national innovation ecosystems.

In the United States, NASA grants and contracts awarded to HEIs are regularly reported and the data are made available to the public. These organisations can be found in the categories "educational" and "non-profit" as non-profit organisations include university-controlled research corporations and institutes (e.g. San Jose State University Research Foundation, Georgia Tech Research Corporation). In 2020, educational and non-profit organisations received in total some USD 1.4 billion in grants and contracts from NASA. This accounted for 7% of all NASA procurement (NASA, 2021[11]). Figure 3.6 shows NASA procurement awards to educational and non-profit organisations over the last decade.

Role of international organisations and other institutions in the space economy

The space economy is characterised by a high level of international co-operation and many space missions and activities are carried out by international organisations which do not have resident status in any particular country. In the *Frascati Manual*, R&D activities conducted by international organisations are considered part of the "Rest of the World" sector. This sector "consists of all non-resident institutional units that enter into transactions with resident units, or have other economic links with resident units" (OECD, 2015[19]). More concretely, this category includes:

- all institutions and individuals without a location, place of production or premises within the economic territory on which or from which the unit engages and intends to continue engaging, either indefinitely or over a finite but long period of time, in economic activities and transactions on a significant scale
- all international organisations and supranational authorities, including facilities and operations within the country's borders.

This includes for example contributions to organisations such as the European Union, the European Space Agency, the European Southern Observatory (ESO), the European Centre for Medium-Range Weather Forecasts (ECMWF) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). These organisations are often European, but membership is open to non-European countries. To these larger organisations can be added a number of smaller-scale organisations and networks focusing mainly on different types of scientific co-operation. Smaller international organisations include the European Incoherent Scatter Scientific Association (EISCAT) and the International Scientific Optical Network (ISON). A more detailed but still non-exhaustive list is provided below in Table 3.2.

Table 3.2. Selected international space organisations

Organisation	Fields	Host economy/country	Membership	Approximate annual budget size (USD)
European Space Agency (ESA)	ESA space programmes	Multiple centres in Europe. Headquarters in France	22 full members and 4 associated members	USD 7.3 billion
European Union Agency for the Space Programme (EUSPA)	EU space programmes	Czech Republic	28 full members (EU)	USD 2.3 billion (2021)
Eumetsat	Space-based weather observations	Germany	30 members	USD 721 million (2017)
European Southern Observatory (ESO)	Astronomy, astrophysics	Germany	16 members	USD 260 million (2017)
European Centre for Medium-Range Weather Forecasts (ECMWF)		United Kingdom	23 members and 12 co-operating states	USD 120 million (2017)
European Incoherent Scatter Scientific Association (EISCAT)	Ionospheric and atmospheric research	Facilities in Norway, Sweden and Finland. Headquarters in Sweden	9 members	USD 5 million (2017)
Square Kilometre Array Observatory (SKAO)	Radio astronomy	Observatories in Australia and South Africa. Headquarters in the United Kingdom	8 members and 8 observers	Construction and first ten years of operations budgeted to about USD 2.1 billion (2020)
Asia Pacific Space Cooperation Organisation (APSCO)	Multiple areas of regional co-operation	People's Republic of China	8 members	n.a.
Asia-Pacific Regional Space Agency Forum (APRSAF)	Multiple areas of regional co-operation	Japan	52 members	n.a.
International Scientific Optical Network (ISON)	Astronomy	Russian Federation	About 12 members	n.a.

Note: n.a.= Not available.

International organisations may play a role similar to that of government agencies and research institutions in terms of funding and stimulating space activities at the local, regional or even national level. The European Space Agency has by far the largest budget (USD 7.3 billion in 2021) of all space-related international organisations (which is to a large extent redirected to ESA member states through contracts according to the geo-return principle). ESA centres in the United Kingdom (Harwell) and the Netherlands (ESTEC) are part of important European regional clusters. As an illustration, the ECMWF is one of the top recipients of Horizon 2020 R&D funding in the United Kingdom for the space segment (FFG, 2021[23]).

Role of business enterprises in the space economy

Governments account for the lion's share of space activity funding and many R&D activities are led by the public sector, but the number and diversity of business enterprises performing space R&D activities are growing all over the world. Understanding the level of participation and the performance of domestic business enterprises is challenging for governments, as space services become ever more pervasive in an increasing range of economic activities. As with other niche areas of the economy, space activities are only partially visible in the structural business statistics produced by national statistics offices.

The *Frascati Manual* defines business enterprises as follows (OECD, 2015[18]):

- resident corporations, regardless of the residence of shareholders, also including all other types of quasi-corporations
- unincorporated branches of non-resident enterprises […], which are engaged in the production on the economic territory on a long-term basis
- resident non-profit institutions that are market producers of goods or services or serve business.

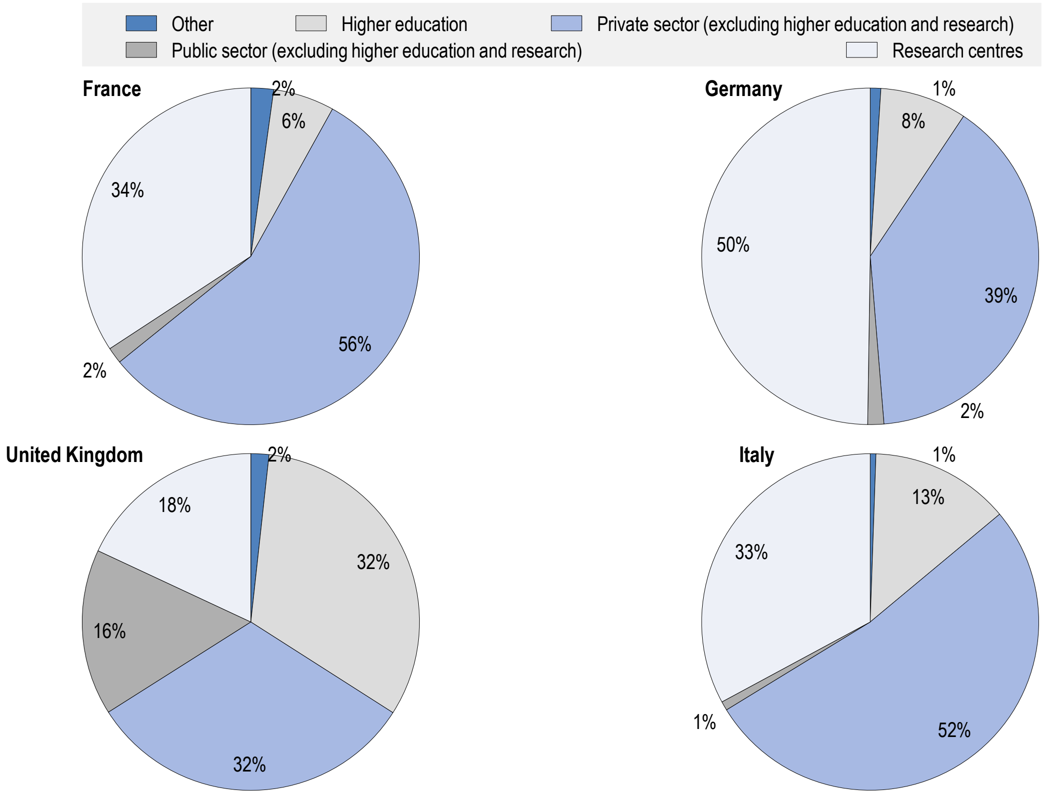
The sector comprises both private and public enterprises. If public-private partnerships have the status as institutional units, the classification depends on the institution with the greatest interest in the partnership. The activities of enterprises can be identified, outlined and understood using the tools described in the previous sections for the government sector and HEIs. Notably through the use of official statistics, industry surveys (business demographics and detailed activities) and grants and contract information.

Official statistics: National statistical business registers (e.g. tax registers) are the primary and preferred source of information for business demography statistics (OECD/Eurostat, 2008[25]). However, their applicability for space sector statistics varies considerably across countries and depends, in part, on the granularity of industrial classifications used in a particular country (see Chapter 2 for a list of industry classification codes). Some countries have specific industrial codes for a limited number of space activities, mainly space manufacturing and launch services (e.g. North America, People's Republic of China). Classification codes for downstream sector activities are even scarcer. The only distinct downstream "space" category in the International Standard Industrial Classification (ISIC) and the North American Industry Classification System (NAICS) is "satellite telecommunications" (OECD, 2012[26]). Neither therefore captures the breadth of space activities currently carried out by business enterprises. As noted previously in the section on Government R&D performers, the performance of R&D by business enterprises can, in principle, be tracked by the socio-economic objective for the exploration and exploitation of space. In practice, very few countries record this information.

Industry surveys: Targeted space industry surveys can provide detailed information about business demography (company size, employment), turnover and activities in the space sector. They are mostly conducted by industry associations. For example, the Satellite Industry Association in the United States, Eurospace and the European Association of Remote Sensing Companies in Europe and Society of Japanese Aerospace Companies in Japan. They may also be conducted by government agencies (e.g. Australia, Canada, France, Germany, Korea, Norway, and Sweden). Space industry surveys are addressed specifically in Chapter 4.

Figure 3.7. Breakdown of Horizon 2020 space-related grants by institutional categories

Share of total space-related grants received by institutional sectors between 1 January 2014 and 4 October 2021



Note: Horizon 2020 institution categories do not correspond to the institution categories in the *Frascati Manual*. In the *Frascati Manual*, research centres are mainly categorised under "Higher Education" or "Government sector".
Source: French Ministry of Research and Education (2021[23]), "Participations dans les contrats signés du programme-cadre pour la recherche et l'innovation (H2020) de la Commission européenne", https://data.enseignementsup-recherche.gouv.fr/explore/dataset/fr-esr-h2020_participations-dans-les-contrats-signes/.

Data and information from government contracts and grants: As in the case of government research institutes and HEIs, government procurement data can provide valuable information about business sector space activities and the generation of revenue (how much and by whom). General procurement data can provide an overview of the number and location of business enterprises, whereas R&D procurement data give indications of innovative capability. As an illustration, Figure 3.7shows the breakdown of Horizon 2020 space grants allocated to France, Germany, Italy and the United Kingdom according to the receiving institutional sector.

In France and Italy, business enterprises constitute the single largest institutional group receiving more than 50% of total funding in each country. In Germany and the United Kingdom, business enterprises are surpassed by research centres and HEIs, respectively (French Ministry of Research and Higher Education, 2021[22]).

Identifying specific groups: SMEs and workforce diversity

Sometimes it is necessary to carry out a more granular analysis of the space economy in order to detect specific strengths or vulnerabilities, track the progress of targeted policies, and/or identify relevant trends.

The following sections look more closely at small- and medium-sized enterprises (SMEs), workforce diversity, and the skill composition of employees in space activities.

Small and medium-sized enterprises

It may be useful to classify business enterprises according to their size as they tend to differ in their innovative capabilities, agility and vulnerability to crises (OECD, 2021[26]). The COVID-19 pandemic has also revealed significant vulnerabilities for smaller and younger firms in handling long-term economic shocks (OECD, 2020[27]). Canadian space SMEs account for 46% of all space-related business R&D expenditure (BERD) and 79% of space-related inventions in 2018 (CSA, 2022[9]). In the United States, a Department of Commerce study on the space industrial base found that 92% of space firms with R&D as a primary business line were small businesses (US Department of Commerce, 2013[28]).

SMEs account for the bulk of space business firms but are dwarfed by larger firms when it comes to overall income and employment. In 2019, 94% of Canadian space companies were SMEs (defined as employing 1 to 499 workers), but they accounted for only 42% of Canadian space sector revenues and 29% of employment. In Korea, 91% of space companies had less than 300 employees and accounted for 41% of total sales. Many companies in Korea are very small with companies of less than 50 employees making up 66% of the total number of companies and generating only 8.6% of total sales (Korean Ministry of Science and ICT, 2020[11]).

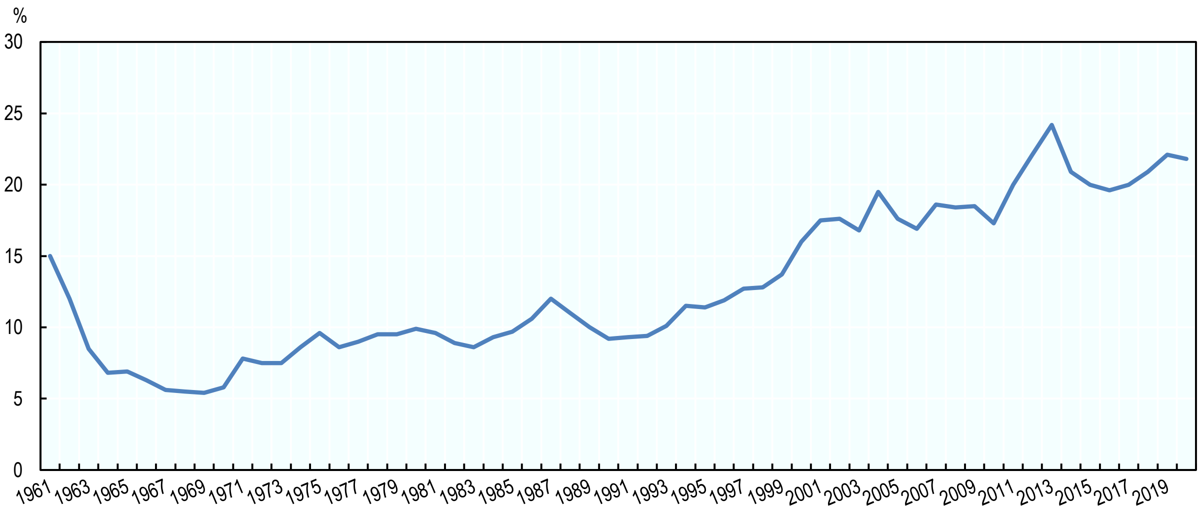
In Europe, associations representing space manufacturing industries (Eurospace) and remote sensing companies (European Association of Remote Sensing Companies – EARSC) track SMEs among their respective members. According to Eurospace, some 8-16% of space manufacturing employment was to be found in SMEs and “unverified” small businesses in 2019 (Eurospace, 2020[13]). EARSC found that in 2020 some 96-97% of European earth observation companies had less than 250 employees (EARSC, 2021[29]).

NASA systematically tracks the participation of “small” businesses in its annual procurement reports. Figure 3.8 shows that small business participation in NASA procurements has been rising steadily since the 1960s, thanks to dedicated programmes such as the Small Business Innovation Research (SBIR) or Small Business Technology Transfer (STTR) programmes (NASA, 2021[10]). According to US Small Business Administration definitions, “small businesses” here refers to those with a maximum of 1 250 employees.

The above-mentioned examples illustrate how practices in defining and recording SMEs differ across sectors and/or countries. This makes direct comparisons between the published statistics difficult. The most frequently used upper limit for employment is 249 employees (OECD, 2012[25]). However, some countries set the limit at 200 employees. The United States and Canada often set it at 499 or more depending on the sector. Sometimes, turnover thresholds are also used. In the European Union, for instance, the turnover of SMEs should not exceed EUR 50 million.

Figure 3.8. Small business participation in NASA procurements

As a share of NASA's procurement budget



Note: "Small businesses" as defined by the US Small Business Administration, include those with maximum 1 250 employees in the "Guided Missile and Space Vehicle Manufacturing" sector.
Source: NASA (2021[10]), "Annual procurement report: Fiscal year 2020".
https://www.nasa.gov/sites/default/files/atoms/files/annual_procurement_report_fy20.pdf.

The practice promoted by the *Frascati Manual* and the *OECD Entrepreneurship at a Glance* reports (OECD, 2017[30]) uses a classification of enterprises based solely on the number of employed persons with the following breakdowns:

- 1-9 employees: Micro enterprises
- 10-49 employees: Small enterprises
- 50-249 employees: Medium enterprises
- 250+ employees: Large enterprises.

Another challenge is ownership. SMEs that are dependent (e.g. owned by a larger domestic or foreign firm) may be treated differently statistically than independent SMEs, while sharing many of the same characteristics. As noted above, the industry association Eurospace faces challenges in precisely estimating the population of SMEs in upstream space activities in Europe. The uncertainty is linked to the European Union's definition of an SME, which requires it to be independent (i.e. that its capital is not controlled by a non-SME). However, for some business demographic analyses it may make sense to separately identify independent and dependent SMEs (OECD, 2019[32]).

Workforce diversity

Learning more about the composition of the space workforce is important as, when combined with information on the supply of workers, it can indicate potential recruitment challenges. Furthermore, there are many benefits to a diverse workforce and increasing workforce diversity is a priority in many OECD member countries. These aspects are useful for tracking specific policy objectives such as gender equality or demographic trends in the space economy.

Some industry surveys record the age of the workforce. In the United States, a 2013 space industrial base assessment found that some 36% of the space-related workforce were 50 years or older and that small and very small enterprises were more likely to have older workforces on average (US Department of Commerce, 2013[28]). The European space manufacturing workforce has a similar age structure according to the 2020 Eurospace space industry survey (Eurospace, 2020[13]). In contrast, the 50+ age group accounted for less than 11% of space industry workers in Korea in 2019 as reported by the Ministry of Science and ICT's latest space industry survey (Korean Ministry of Science and ICT, 2020[11]). Similarly, in the United Kingdom, those aged 55 and over account for some 17% of the space workforce according to the 2020 UK space census (Thiemann and Dudley, 2021[32]). National differences in the retirement age will affect the comparability of these statistics.

An increasing number of space agencies and government agencies track gender participation in the workforce. Overall, more men than women are employed in the space economy irrespective of sector and fields – from government (Table 3.3) and research sectors to private sector manufacturing and service provision (OECD, 2019[33]). Korea, which also collects data on gender participation in the public sector, found that 13% of the workforce in space-related government research agencies and 5.7% of university professors in space-related fields were women (Korean Ministry of Science and ICT, 2020[11]). In the private sector, women accounted for 13.3% of space sector employment in 2019 in Korea, while in the United Kingdom the equivalent share was 36.5%. Eurospace, which concentrates on employment in space manufacturing, launch and operations, recorded 22% female employment in 2019 (Eurospace, 2020[13]). In the Canadian space sector, which in the survey comprises both private and public (including academic) organisations, 28% of the workforce identified as female (CSA, 2022[9]).

Table 3.3. Share of women in scientific and/or management occupations in space organisations in selected OECD countries and partner economies

Economy/region	Canada	South Africa	France	United States	Germany	Europe	Japan	India
Organisation (year)	CSA (2017)	SANSA (2017)	CNES,(2014)	NASA (2017)	DLR (2017)	ESA (2016)	JAXA (2015)	ISRO (2017)
Share of total staff	47%	39%	37%	34%	32%	26%	22%	20%
Share of "non-administrative" and/or "non-clerical staff[1]	23% (scientific and professional positions)	37% (engineers and scientists/ researchers)	26% (engineers)	23% (science and engineering occupations)	20% (scientific staff)	21% (executive staff, translators and "off-scale", e.g. directors, staff)	12% (researchers)	16% (science and technology occupations)

1. This category typically refers to women in science and engineering occupations, but definitions and data availability vary across organisations.
Source: OECD (2019[33]), "Remedying the gender gap in a dynamic space sector", https://dx.doi.org/10.1787/9405a5a2-en.

The United Kingdom measured the space workforce in its first comprehensive demographic survey in 2020 – the 2020 Space Census (Thiemann and Dudley, 2021[33]). The study, which drew on a sample from industry, academia, government, the military and the non-profit sector, looked at gender, sexuality, ethnicity, age, nationality, and disability and compared results with findings in the general workforce population and the workforce of similar sectors (e.g. science and maths, engineering, technology).

Workforce skill composition

Finally, keeping track of the skill levels in the space workforce can give a better understanding of the human capital available to a particular activity, which is associated with the capacity of a particular organisation to innovate.

OECD's *Oslo Manual*, which provides guidelines for collecting, reporting and using innovation data, recommends recording the share of employed persons that have completed tertiary education (OECD/Eurostat, 2018[34]). Tertiary education here corresponds to the International Standard Classification of Education (ISCED 2011) levels 5-8 (UNESCO Institute for Statistics, 2011[35]):

- **Level 5:** Short-cycle tertiary education: Short first tertiary programmes that are typically practically-based, occupationally-specific and prepare for labour market entry. These programmes may also provide a pathway to other tertiary programmes.
- **Level 6:** Bachelor's or equivalent: Programmes designed to provide intermediate academic and/or professional knowledge, skills and competencies leading to a first tertiary degree or equivalent qualification.
- **Level 7:** Master's or equivalent: Programmes designed to provide advanced academic and/or professional knowledge, skills and competencies leading to a second tertiary degree or equivalent qualification.
- **Level 8:** Doctorate or equivalent: Programmes designed primarily to lead to an advanced research qualification, usually concluding with the submission and defence of a substantive dissertation of publishable quality based on original research.

Traditionally, fields of education of particular importance to research and development include natural sciences, mathematics and statistics; engineering (including manufacturing and construction); health and medicine; information and communication technology; and media and design. But the humanities and social sciences are increasingly considered important fields of expertise in the development of innovative activities.

The *Oslo Manual* further encourages the collection of data on occupational status based on the International Labour Organisation Standard Classification of Occupations (ISCO-08) (ILO, 2016[36]). This includes occupations such as "science and engineering professionals", "information and communications technology professionals", and "science and engineering technicians".

A number of countries gather information on elements of workforce skills in their space sector surveys, concentrating particularly on educational attainment and/or occupations. The space economy workforce tends to be highly educated. In the United Kingdom and Canada, 77% and 66%, respectively, of space economy employees had a bachelor's degree or more in 2019 (CSA, 2022[10]; UK Space Agency, 2021[16]). Eurospace, which reports Europe wide for the upstream activities, has recorded 73% of the workforce as having three-years of university education or more. The countries that distinguish between upstream and downstream activities in their recording find a concentration of the highly educated in the upstream sector.

In terms of recording specific types of occupations, the Japanese space industry survey identifies "R&D occupations" comprising 45% of the space workforce (SJAC, 2021[14]). The Canadian space industry survey singles out "STEM" occupations, covering engineers, scientists, technicians, management, health professionals and students and measures them as representing some 63% of the workforce (CSA, 2022[9]).

The evolving cast of space actors: Key take-aways

This chapter has provided an overview of the roles of different sectors in the space economy and how the space activities of organisations in each sector are monitored and understood. Significant national efforts are underway to better understand the space economy, and good practices are beginning to emerge, but such exercises remain challenging. For the most part, information on the performance of space activities is not comparable across sectors or between countries.

The following points summarise some of the key findings of this chapter with regards to the type of information that could be collected by countries seeking to better understand the organisations operating in their space economies. It is hoped that this will inspire more countries to collect and share these types of data and to streamline collection practices in order to maximise the utility of data collection efforts. Further discussions on industry surveys follow in Chapter 4.

Make better use of official statistics and collect more granular data: While official statistics are generally too aggregated for space activities to be readily visible, some official data sources can provide useful information. Notably: national accounts, national R&D statistics and national education statistics.

However, these need to be supplemented by more granular data from, most importantly: Industry and other sectoral surveys, annual reports from individual organisations, and, when available, grants and contract data.

Rely on internationally recognised definitions and practices: For better internationally comparable information, use internationally recognised definitions and practices in future space economy surveys. For SMEs for example, the following breakdowns are encouraged based on the OECD's *Frascati Manual* (and they are included in the model questionnaire in Annex 4.A.):

- 1-9 employees: Micro enterprises
- 10-49 employees: Small enterprises
- 50-249 employees: Medium enterprises
- 250+ employees: Large enterprises.

Further, considering the high rate of foreign ownership and vertical integration in the business enterprise sector, separately identifying dependent and independent SMEs would provide a more complete idea of business demographics.

Similarly, applying internationally recognised definitions (such as those provided by the *Frascati Manual*) for higher education institutions, government sector and non-profit institutions would greatly facilitate international comparability. The same applies to educational attainment (ISCED-2011) and occupations (ISCO-08).

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4 Using industry surveys to better understand the space economy

Drawing on established international guidelines and experiences in the space community, this chapter outlines good practices for conducting surveys of the space economy and presents a model questionnaire to spur international comparability.

Introduction

Collecting information on the space economy via surveys is a valuable tool for public policymakers and private decision makers to understand space activities and their broader effects.

This chapter is the result of extensive research into the principles and best practices of industry surveys. The information provided is grounded in international standards such as the *Frascati* and *Oslo Manuals* (OECD, 2015[1]; OECD/Eurostat, 2018[2]) with specific lessons learnt from the space community. This work has also benefited from OECD Space Forum members' insights and expert inputs from different administrations, industry associations, academia and the private sector. Special insights from the Canadian Space Agency (CSA) and the German Space Agency (DLR) have contributed to a practical guidance tool for future developers of space industry surveys. These insights are referenced throughout the text and summarised in Annex 4.B (Fischer et al., 2021[3]).

Conducting a survey, and in particular initiating a new survey, can be challenging. Time and resources are required to design a robust survey; identify, contact and reach out to respondents; answer questions from stakeholders concerning the survey design itself; maintain the data collection process; and pre-process and validate results. The burden on respondents should not be underestimated, and the survey should be designed in order to minimise the time and effort required to answer it (OECD, 2015[1]). It is therefore important to prepare surveys with care and to:

- identify potential synergies with existing national/industry surveys or specific events requiring data (e.g. regular Ministerial meetings of the European Space Agency)
- use national/international statistical classifications to ensure comparability across industries and countries where possible
- make it a repeated exercise over a regular period (e.g. annually or biennially). Organisations with limited resources may choose to reduce the survey frequency even further (e.g. once every four or five years) to limit the burden both on the government organisation and reporting units. The main trade-offs of having a low survey frequency are the recurring lack of up-to-date statistics on which to base policy decisions and the added effort to reconnect with respondents.

The following sections review some of the key points and principles for conducting a survey, providing best practices and lessons learnt. Selected categories that might be included in a model questionnaire are also outlined, as well as practical step-by-step approaches and recommendations for future surveys. A model questionnaire is also proposed in Annex 4.A to spur further international comparability.

A brief review of existing space industry surveys

The OECD has reviewed more than twenty questionnaires used to conduct regular surveys of the space economy or specific segments of it. All these surveys are referenced in this *Handbook*. Such surveys are essential to providing an indication on the size and health of the space economy (or of specific segments) at the national level and can provide the more granular information needed to support decision-makers in both the public and private sectors. The statistics they provide can also be key to assessing broader socio-economic impacts using different techniques like input-output analysis (see more on measuring impacts of space activities in Chapter 5).

In addition to these regular surveys, there are many more one-off studies exploring the economic effects of space activities, including for specific missions or segments of the space sector, that are based on ad-hoc questionnaires and expert opinion (Deloitte, 2019[4]; Dialogic, 2021[5]; Australian Space Agency, 2021[6]). Many of these studies are led by consulting firms on behalf of public administrations and provide a snapshot of the national space economy within a particular period. Some of these ad-hoc studies also review the broader effects of space activities on society. Finally, commercial market assessments provide additional information on the developments in diverse space markets (e.g. studies from Bryce Space and Technology, Euroconsult, Northern Sky Research, PwC, etc.).

Regular national and regional surveys are the focus of the following sections. Relatively few countries and organisations conduct annual or biennial measurements of their space economy. Table 4.1 gives an overview of selected surveys and reveals the approaches taken by different organisations.

Table 4.1. Selected space sector surveys

Survey name (responsible organisation)	Type of survey organisation	Coverage and target population	Sample size and response rate	Targeted economic activities	Survey status	Number of questions	Frequency
La filière aéronautique et spatiale (INSEE France)	National statistical agency	National, regional, firms	+1 500 (medium response rate, but narrow scope with good industry representativeness)	Aeronautics and space	Mandatory	25-30 questions (9 pages)	Annual since 2019 (regional since 1982)
US space industrial base and supply chain survey (US Department of Commerce)	Government agency / National statistical agency	National, administrations, firms, higher education, non-profit	+3 700 (high response rate)	Space manufacturing	Mandatory	+40 questions depending on the actor (46 pages)	Every 5-7 years). Last conducted 2011-13, new survey in 2022
State of the Canadian space sector (Canadian Space Agency)	Government agency	National, firms, higher education, non-profit	+200 (high response rate)	Upstream and downstream activities	Voluntary	15-20 questions	Annual (since 1996)
Economic ripple effects of ESA membership (Norwegian Space Agency)	Government agency	National, firms	+20 (high response rate)	Space goods and services	Voluntary	1-5 questions	Annual (since 1992)
Space industry survey (Swedish National Space Agency)	Government agency	National, firms	+ 50 respondents (medium response rate)	Upstream and downstream activities	Voluntary	5-10 questions	Annual
Size and health of the UK space industry (UK Space Agency)	Government agency	National, firms, higher education, non-profit	+1 000 and growing (rather small response rate, but desk research and very large scope)	Upstream and downstream activities	Voluntary	15-20 questions	Biennial (since 2010) to become annual in 2022
Space industry survey (Korea Aerospace Research Institute)	Industry association	National, firms, higher education, non-profit	+400 (high response rate)	Upstream and downstream activities	Mandatory	15-20 questions	Annual (since 2005)
Facts and figures (Eurospace, Europe)	Industry association	Europe, firms	+400 (medium response rate depending on the year, but narrow scope with excellent industry representativeness)	Space manufacturing	Voluntary	+20 questions (employment, sales and corporate information)	Annual (since 1991, major update in 2009)

Survey name (responsible organisation)	Type of survey organisation	Coverage and target population	Sample size and response rate	Targeted economic activities	Survey status	Number of questions	Frequency
State of the satellite industry (Satellite Industry Association)	Industry association	United States, global	Varies. Based on ad-hoc survey, interviews of selected firms and desk research	Upstream and downstream activities	Voluntary	n.a.	Annual
State and Health of the European EO Services Industry (European Association of Remote Sensing Companies)	Industry association	Europe, firms	+700 (medium response rate but narrow scope with good industry representativeness)	Earth observation	Voluntary	n.a.	Biennial (since 2013)
Space industry survey (Society of Japanese Aerospace Companies)	Industry association	Japan, firms	+90 (high response rate)	Mainly space manufacturing	Voluntary	10-15 questions	Annual

Note: n.a.= Not available.

There are three main categories of surveys collecting data on space activities at national levels. The first group includes surveys developed by national statistical agencies and administrations to produce official structural business statistics (e.g. the French National Institute of Statistics and Economic Studies (INSEE) surveys, US Department of Commerce survey of the space industrial base) (US Department of Commerce, 2015[7]; INSEE, 2021[8]). The benefits of surveys conducted by statistical authorities include extensive sectoral coverage and comparability with other areas of the economy. Targeted organisations are often legally obliged to respond and must provide information that can be crosschecked with other administrative sources (e.g. tax data). A drawback is that the resulting statistics are usually aggregated due to confidentiality issues and other reasons for withholding specific information. Space activities are often therefore embedded in larger sectors like aerospace, information and communication technologies and defence. This leads to a lack of granularity (Box 4.1). Timeliness can also be an issue – the data might refer to performance two or three years behind the current year. Still, broad national industry surveys conducted by statistical authorities with well-targeted questions, often developed in cooperation with space agencies and/or industry associations, can be highly coherent with other official statistics.

A second category of surveys are conducted by space agencies, either in-house (e.g. Canadian Space Agency, Norwegian Space Centre, German Aerospace Centre, United Arab Emirates Space Agency) or subcontracted to consultants (e.g. Korea Aerospace Research Institute, United Kingdom Space Agency, The Netherlands Space Office, the Federal Belgian Science Policy (BELSPO)'s Space Research and Applications department) (Korean Ministry of Science and ICT, 2021[7]; London Economics, 2019[8]; CSA, 2020[9]; know.space, 2021[10]). One advantage to conducting surveys in-house is the opportunity to develop internal industry expertise and use distinctive administrative resources for designing and following up with survey respondents (e.g. listing business enterprises receiving grants or contracts). Furthermore, government space agencies may be better qualified than external actors to identify and delineate the target survey population, leading to more accurate results. However, this approach calls for the mobilisation of significant internal resources and time, with several people involved for the duration for the survey (Fischer et al., 2021[3]). Outsourcing the survey is therefore another option, when such resources cannot be devoted in-house. Many consulting firms and research organisations are now providing ancillary services to space administrations in this manner. Outsourcing helps find the right expertise and limits the strain on existing staff or the need for dedicated internal resources. However, there are many challenges associated with outsourcing. Due to procurement rules, the consulting firm might change from one study to the next, and the surveyed organisations are unlikely to share data and business strategies with a company that they do not know or trust. Other drawbacks include a lack of control over the data collection process, possible statistical quality matters, and potential confidentiality issues on contracts and other sensitive statistics. It still represents the only available option for some space agencies.

Box 4.1. An illustration of official surveys: INSEE surveys of aeronautics and space industries

The French National Institute of Statistics and Economic Studies (INSEE) has conducted regional surveys of the aeronautics and space industries since the mid-1980s at the regional level (since 1982 in Midi-Pyrénées and since 2000 in Aquitaine). The original regional surveys have led to a broader series of national surveys since 2019. The 2020 survey covers the whole of France (excluding French Guiana) (INSEE, 2021[6]). In parallel, the Interregional Directorate of INSEE Antilles-Guyane is carrying out a survey on the impact of space activities on the French Guyanese economy in partnership with the Guiana Space Center.

The next round of analysis aims to delimit better the perimeter of aeronautics and space activities in France and measure the contribution of each to the national economy. It will provide data on the aerospace industry (function, range, customers), its outlook (evolution of the activity, recruitment), human resources and innovation. Using the French classification of products (NAF based on CPF rev. 2.1), the space industry is defined by the units of the aerospace sector (3030Z, 5122Z), by the "partial" sectors units (2051Z, 2562B, 2651A, 3316Z), and "potential" areas units (40 classes of activity NAF).

By definition, INSEE surveys provide relatively aggregated statistics. But, as seen in Chapter 2, policy demand for detailed statistics on the French space economy is increasing. The French space agency CNES has recently begun a partnership with the INSEE to explore a new statistical approach for measuring the space economy using satellite accounts to the core national accounting system.

The third and final category of surveys are conducted by industry associations (e.g. Eurospace, European Association of Remote Sensing Companies (EARSC), Society of Japanese Aerospace Companies) – based on regular questionnaires sent to their membership and beyond (EARSC, 2019[13]; Eurospace, 2021[14]; Society of Japanese Aerospace Companies, 2021[15]). Some organisations outsource their industry data collection and analysis (e.g. Satellite Industry Association with Bryce Space and Technology, LLC) (Satellite Industry Association, 2021[16]). Such proprietary surveys of business enterprises provide up-to-date annual industry data. The timeliness is useful, as official statistics tend to take longer to be collected and curated. In some cases, limitations may arise in the scope of the survey, which may be focused on one segment of the space economy. Issues related to data openness normally mean that detailed results are reserved for industry association members.

The surveys reviewed in this chapter vary considerably in scope, respondent types and the number and subject of the questions asked.

- The number of organisations responding to the surveys outlined in Table 4.1 range from less than 50 to several thousand. The type of organisations surveyed also differ from those focused solely on business enterprises to those that also target public and non-profit research organisations and higher education institutions.
- The target population of space industry surveys may also change over time (know.space, 2021[10]). Whereas space manufacturing and other upstream activities used to be a major focus of industry associations (Table 4.2), many organisations now try to extend the scope to downstream activities and applications. This also affects the type and number of respondents.

- The number of questions included in questionnaires varies from just a couple of questions to more than a hundred. Mandatory surveys (e.g. US Department of Commerce) tend to be much longer than those that are voluntary.

Some lessons learnt from these and other surveys will provide the principles and best practices described in the next sections.

Table 4.2. Selected space industry associations

Country/Region	Industry associations	Annual statistics	Website
Australia	Space Industry Association of Australia (SIAA) Australian Association of Aviation and Aerospace Industries (AAAAI)	No	www.spaceindustry.com.au/, www.aviationaerospace.org.au
Brazil	Associação das Indústrias Aeroespaciais do Brasil (AIAB)	Yes	www.aiab.org.br
Canada	Aerospace Industries Association of Canada (AIAC)	Yes	http://aiac.ca/
Europe	AeroSpace and Defence Industries Association (ASD)	Yes	www.asd-europe.org/
	Eurospace conducts surveys of the space industry and provides results to ASD	Yes	www.eurospace.org
	European Association of Remote Sensing Companies	Yes	http://earsc.org/
France	Groupement des Industries Françaises Aéronautiques et Spatiales (GIFAS)	Yes	www.gifas.asso.fr/
Germany	German Aerospace Industries Association (BDLI)	Yes	www.bdli.de
India	Society of Indian Aerospace Technologies and Industries (SIATI)	No	www.siati.org
Italy	Associazione delle Industrie per l'Aerospazio i Sistemi e laDifesa (AIAD)	Yes	www.aiad.it
Japan	Japanese Aerospace Industries Association (SJAC)	Yes	www.sjac.or.jp
Spain	Spanish association of defence, security, aeronautics and space technology companies (TEDAE) with a dedicated space section	Yes	www.tedae.org
United Kingdom	United Kingdom Aerospace, Defence and Security Group	Yes	www.adsgroup.org.uk/
United States	Aerospace Industries Association (AIA)	Yes	www.aia-aerospace.org/
	Satellite Industry Association (SIA)	Yes	www.sia.org/

Principles for a successful space industry survey

Key principles and guidelines for conducting surveys on economic activity linked to research and innovation are well documented (OECD, 2015[1]; OECD/Eurostat, 2018[2]). The following sections provide some basic principles as they may apply to surveys in the space economy. For broader considerations on R&D and innovation, the *Frascati* and *Oslo Manuals* provide a wealth of information on approaches to measuring R&D and innovation. These manuals enable the production of internationally comparable survey results and should be considered key reference documents.

The information provided below has been intentionally kept general in order to be useful to different types of organisations interested in developing surveys. However, it also provides brief pointers and lessons learnt from the comparative study of existing questionnaires. This may give ideas to new surveyors and long-standing developers of surveys alike.

When putting together a survey, there are several standard elements to consider: The scope and objectives of the survey, the target population, the data collection modes to be used, the questions asked, validation of the results and the need to complement the survey with other data.

Scope and objectives: Designing the survey

The first step when preparing a survey of the space economy is to clearly identify the objectives and delimit the scope of the exercise. It is important that the survey scope is aligned with initial strategic objectives, making it possible to then report back on policy priorities.

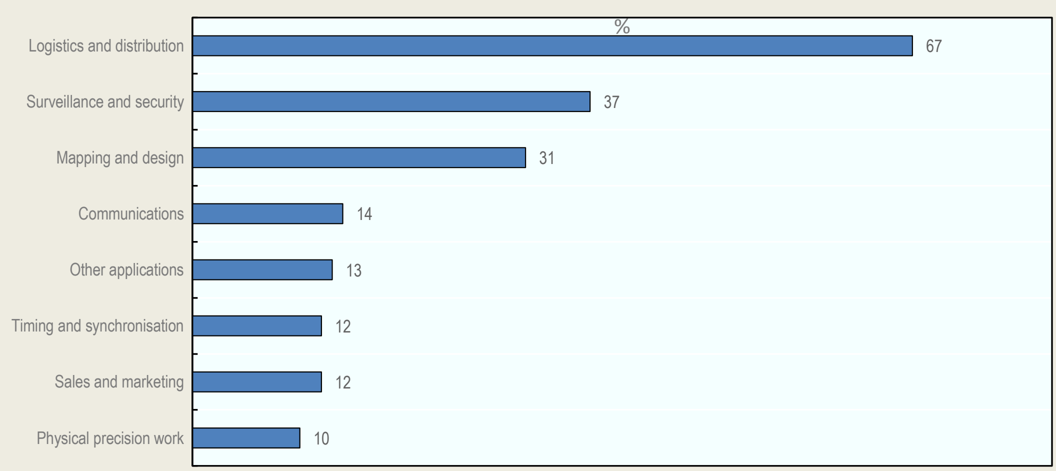
In most cases, surveys aim to provide information on the state of the space economy or segments of it (manufacturing, academic capabilities, etc.), by identifying key actors, their demographics, outputs and outcomes such as revenues or innovations (Eurospace, 2021[14]). Increasingly, an additional objective is to conduct further economic impact analysis based on the statistics gathered (employment and revenues), such as input-output analysis for example (Korean Ministry of Science and ICT, 2021[9]; Canadian Space Agency, 2020[10]) (more details on techniques in Chapter 5). Another objective might be to survey the *users* of space products and services. Denmark Statistics, for example, has added space-related questions to two nation-wide annual surveys: “ICT use in enterprises” and the “Agricultural and horticultural survey” (Box 4.2).

Box 4.2. Tracking users of space applications via official statistics in Denmark

Since 2016, Statistics Denmark has included questions on the use of space technologies and satellite data in the broader economy in two national economic surveys. This makes it possible to track the use of space technologies and satellite data at a much larger scale than what is commonly possible from space-related surveys. The OECD Space Forum supported the development of the initial questions. The first survey targets Danish business enterprises in all sectors and asks about their ICT uses. It includes questions on the use of global navigation satellite systems and other satellite services. The survey found that in 2018 some 16% of Danish enterprises used satellite-based services (Figure 4.1).

Figure 4.1. Main applications of satellite-based services in Danish enterprises

Share of enterprises using satellite-based services, 2017



Note: The results are based on data from 3 954 enterprises out of a total population of 16 465 enterprises.
Source: Danish Ministry of Higher Education and Science (2018[15]), *Opfølgning på den danske rumstrategi* [Follow-up report to the Danish space strategy], http://www.ufm.dk/brugrummet.

This original approach using broad national industry surveys with short and targeted questions may identify unexpected user groups. In 2018, 77% of “large” Danish enterprises (250+ employees) in all surveyed sectors had used satellite-based services. In individual areas of the economy, 32% of enterprises in the construction sector, 18% in trade and transport and 10% in ICT had used satellite-based services (Danish Ministry of Higher Education and Science, 2018[15]).

Once the objectives of the survey are well defined (e.g. status of the national space economy, status of the space manufacturing sector, etc.), a consultation with key stakeholders should take place. Stakeholders may be organisations conducting space activities from any sector. This enables potential respondents to the survey to contribute to its design with the aim of reducing the survey burden once it is live. A period of testing and refining questions will be required.

The next step is to allocate resources. As mentioned earlier, whether small or large, conducted in-house or contracted out, surveys represent an investment both financially and in terms of human resources (Fischer et al., 2021[3]). A timeline with defined milestones also needs to be developed, particularly if potential collaboration and possible overlaps with other surveys have been identified.

To conduct successful surveys, one important principle is to ensure that the survey design is robust to the pressures associated with changing circumstances in the space economy. This implies careful thought regarding both the questions asked and how they may be adapted in the future. Both the Canadian Space Agency survey, and most recently the UK Space Agency survey, have extended or changed their methodologies in such a way as not to disrupt their long time series. Approaches that enable statistics to be presented in time series form are preferable to ad-hoc surveys. A good example is the Eurospace survey which has been conducted for more than 20 years (Box 4.3).

Box 4.3. Example of a robust space industry survey: The Eurospace survey

Eurospace is a space industry association that has been collecting data on European space manufacturing for more than 20 years (Eurospace, 2021[12]). The data collection is supported by business enterprises operating in Europe but is not limited to Eurospace membership. Respondents answer a questionnaire providing detailed information on their sales and employment relevant to space system design, development and manufacturing. For enterprises not directly responding, proxy data are elaborated using information provided in previous years (when available) and/or information available from public sources such as the European Space Directory, media sources and company websites.

The survey relies on well-established processes. It has by definition a focus on space manufacturing, but it also covers other space economy activities. To avoid double-counting, Eurospace calculates consolidated sales at the European level, while also taking into account intermediate sales throughout the space manufacturing value-chain where possible. The survey methods (including changes in methodology) are publicly available and the resulting long time-series make the survey a robust and respected instrument to track developments in the European space manufacturing space sector. The results have also proven to be a useful baseline for other broader surveys.

Target population

Organisations to be surveyed, or “reporting units”, need to be carefully selected, since respondents are the most valuable resource in the survey process (OECD, 2015[1]).

Unless a census is conducted of a specific sub-set of organisations operating in the space economy, a representative sample of respondents must be selected from the target population. The characteristics of the reporting units and the response rate realised will decide the representativeness of the survey sample and therefore the robustness of the results. In order to improve the quality of its results, the Eurospace industry association, for example, seeks responses from business enterprises that represent some 80% of revenues in European space manufacturing annually (Eurospace, 2021[12]).

Several OECD seminars and workshops have reflected on national practices in surveying subsets of the population of organisations operating in the space economy – from those groups of organisations operating in very broad areas of the space economy to those with very narrow characteristics. The target population should be based on the surveys' objectives. For example:

- **Surveying beneficiaries of public space funding:** In 2021, BELSPO initiated its second space survey (the first one took place in 2016) with the objective of monitoring the status of the space economy in Belgium. BELSPO targeted a specific subset of space organisations and directed the survey only to actors that received public funding (including ESA and Horizon 2020 grants). Such organisations were asked to report and quantify their upstream, downstream and space-related activities (based on *Handbook* and *OECD Frascati Manual* definitions). The sample included public and private entities that were already beneficiaries of public funding. The survey collected information on 160 actors (125 companies and 35 semi-public organisations or universities) identified by their tax identification number to enable checks for consistency with the data available in the National Statistical Office's microdata archives (Teirlinck, 2021[16]).
- **Surveying actors involved in space research:** Also in 2021, the Netherlands Space Office conducted several analyses of the Dutch space economy either directly or via contractors. One report commissioned by the Dutch Ministry of Education, Culture and Science, provided a qualitative and quantitative picture of the activities of groups specifically involved in space research in the Netherlands (Dialogic, 2021[4]). Targeting some 56 research institutes and universities, the survey contributed to mapping the capacities and positioning of Dutch research in European and international space programmes.
- **Surveying actors in earth observation and data analytics:** In this same vein of conducting targeted surveys, the French space agency initiated an internal industry survey in 2019 directed at French business enterprises involved specifically in earth observation and data analytics. Building on CNES grantees and on recent hackathon participants to build a survey population, the survey provided a new picture of the organisations involved in French earth observation activities with a particular focus on identifying start-ups.

The construction of a list of organisations that may form the target population for a typical space economy survey is therefore highly dependent on the scope and objectives of the survey. A typical way forward for deciding the target population may involve one or more of the following steps:

- List companies, public research institutions and universities which are known to participate in space programmes (identified via contracts, grants).
- Enlarge the search to other space-related organisations (via industry and professional associations' memberships, public and private business incubators, official business registers).
- Filter out irrelevant actors through desk research and a possible preliminary screening (i.e. contacting some companies directly to check if their activities fall within the scope of the survey or not). As an example, many actors in downstream space activities are registered as data-processing companies (ISIC two-digit code 63: Information service activities and four-digit code 6311: Data processing, hosting and related activities). Based on existing business registries, contact with such companies can help filter them for relevance or reveal other relevant actors for the survey. In the latest UK Space Agency survey, some 1 218 organisations were identified as being engaged in some space-related activities in the UK in the 2018/19 fiscal year (running from 6 April to 5 April the following year) (know.space, 2021[11]). These organisations were all individually assessed by a review of their website or through annual reports.
- Identify start-ups via hackathons, competitions and prizes organised by space agencies (e.g. Space Apps, Copernicus Masters). The EARSC finds that initiatives such as these have simplified

the process of identifying new actors involved in earth observation and data analytics (EARSC, 2019[13]).

- Finally, check commercial online databases (e.g. Crunchbase, ZoomInfo, Owler) to identify start-ups and investor companies using relevant industry categories (e.g. space travel) and keyword searches.

Modes of data collection

When conducting a survey, data collection can be carried out by various modes, including electronic collection, a paper questionnaire or by telephone (OECD, 2015[1]).

Increasingly, questionnaires make use of the internet. A well-designed online questionnaire can be easier for a respondent to interact with than a simple paper questionnaire and the results may be more readily processed into a format suitable for analysis.

Box 4.4. How to boost surveys' response rates?

In order to ensure that the results of surveys are meaningful, survey response rates should be as high as possible. Some best practices for engaging with respondents from space agencies and those derived from the *Frascati* and *Oslo Manuals* (OECD, 2015[1]; OECD/Eurostat, 2018[2]) are provided below:

- ensure good question and questionnaire design including, where necessary, explanatory notes, hypothetical examples and documentation that may be informative for the respondent
- pre-contact respondents to confirm contact information and industrial activity
- clearly communicate the purpose and use of the survey data to generate trust
- use the respondent's name when in contact with them and personalise the wording of reminder emails. Both the Canadian Space Agency and the UK Space Agency include messages from their President/Director-General when contacting respondents.

4.1.1. Drafting the questions

Drafting and testing the questions is a crucial element of the survey process. A model questionnaire is discussed in the next sections, with questions proposed in Annex 4.A, but two general principles borne from recent country experiences can inform the drafting process:

Drafting questions without reinventing the wheel: The German Space Agency launched the first German space survey in September 2020. It targeted around 1 200 space-related companies as well as space research organisations that were identified via desk research and database searches. The structure of the survey closely aligns with the one conducted by the Canadian Space Agency and references the *Handbook* definitions. The questions collect information regarding the positioning of organisations in the value chain; their revenues (national and international, public and private); the level and characteristics of their workforce; their R&D dynamics; and the funding received under the German National Programme for Space and Innovation (Fischer and Grunewald, 2021[17]).

Recognising that different information may be gathered from different target populations: Korea has conducted an annual survey on the status of the Korean space industry since 2005. The survey includes almost 500 business enterprises, R&D institutions and universities that participate in space-related activities and reflect the Korean space sector's supply chain from upstream (e.g. manufacturers of satellite, launcher and ground stations) to downstream (e.g. satellite communication and direct-to-home TV service providers). Based on a 15-year time-series, the survey recently revealed that the number of organisations operating in the country's space economy has grown considerably in the past decade.

According to the 2020 survey, 40% of actors were established after 2005, and 70% started space-related business or research after 2005. To gather information specific to each sector, the Korea Aerospace Industries Association sends out three different versions of its annual space industry survey to business firms, research institutes and higher education institutions (Korean Ministry of Science and ICT, 2021[9]). Sending an “inclusive” questionnaire to organisations from different sectors, with dedicated questions is also another cost-effective approach.

Validating the results and complementing with other data sources

Concerns over the quality of survey data are recurrent in studies of the space economy. It is therefore useful to document the different steps taken and make the methodology utilised publicly available. This may help analysts validate the results and ensure data quality. Such a methodological note should summarise:

- How the list of organisations making up the target population was constructed (which actors and why?), maintained (new actors included?) and assessed for representativeness (which indicators were chosen?).
- Indicators such as the response rate should be included.
- How double-counting issues were addressed. Were revenues consolidated or not? This question may occur particularly when considering revenues of large space prime contractors and their subcontractors. To avoid double-counting for instance, Eurospace calculates consolidated sales at the European level, while trying to determine intermediate sales throughout the space manufacturing value-chain where possible.
- In the case of a repeated survey, evident discrepancies should be indicated (change in the scope from past surveys? More actors were included?) with an explanation of the differences between results over the years.

Using data sources that are complementary to the survey data may also provide a wealth of information that could contribute to corroborating the results. For example:

- Annual reports, business registries and commercial databases can be useful administrative sources. Tax data, when available, can be useful in cases where expenditure on research and development are eligible for tax credits and allow a cross-check with survey results. As an example, the CSA is working with Statistics Canada to identify overlaps between the CSA’s space industry database and official statistical records, which could significantly facilitate quality control or potentially replace certain questions in the survey.
- Other estimates derived from desk research and interviews may be useful. For example, the indirect estimation of R&D expenditures based on modelled estimates. These more subjective estimates need to be substantiated as much as possible.

Towards a model questionnaire

This part of the chapter proposes generic categories and selected questions that may be included in a simplified questionnaire. It builds on both standard practices and lessons learnt from conducting surveys of space activities. The proposed model questionnaire can be found in Annex 4.A.

The model questionnaire aims to encourage better cross-country coherence and improved data availability for space economy analysts. This model is not prescriptive and there will always be differences across countries that will necessitate adjustments. However, its structure is inspired by existing questionnaires and is intended to provide a concrete illustration to practitioners. Definitions of many of the terms used are provided in Chapters 2 and 3. The model questionnaire is split into several sections, each one focused on a particular area of interest. The six suggested sections are:

1. General instructions and definitions
2. Respondent information
3. Revenues
4. Workforce and skills
5. Research, development and innovation
6. Effects of participation in government space programmes.

General instructions and definitions, and the sections on revenues and workforce and skills are included in most long-standing space industry surveys (Table 4.3). The questionnaires often address the business enterprise sector as well as government, higher education institutes and public research organisations.

Table 4.3. Sections and questions in selected space industry surveys

Survey name	Revenues	Workforce and skills	R&D and innovation	Effects of participation in space programmes
La filière aéronautique et spatiale dans le Grand Sud-Ouest[1] (INSEE France)	Space-related revenues	• Space-related workforce (FTEs)	Not applicable	Not applicable
State of the Canadian space sector (Canadian Space Agency)	Space-related revenues by: • sectors • Value chain • Geographic distribution • Customer type	• Space-related workforce (FTEs) • Geographic distribution • Occupations • Gender	• Internal and external R&D expenditure • R&D workforce • Inventions • Patent applications	Revenues generated from products originally supported by public funding
Space industry survey (Swedish National Space Agency)	• Revenues • Geographic distribution • Customer type	• Space-related workforce (headcounts) • Educational attainment • Gender	Not applicable	Not applicable
Size and health of the UK space industry (UK Space Agency)	Income by: • Sectors • Value chains • Geographic distribution • Customer type	• Space-related workforce (headcounts) • Geographic distribution • Educational attainment	• External and internal R&D expenditure	Not applicable
Space industry survey (Korea Aerospace Research Institute)	Space-related revenues by: • Sectors • Geographic distribution • Customer type	• Space-related workforce (headcounts) • Geographic distribution • Occupations • Educational attainment • Gender • Age • Years of experience	• Internal and external R&D expenditure	Not applicable

Survey name	Revenues	Workforce and skills	R&D and innovation	Effects of participation in space programmes
Facts and figures (Eurospace ,Europe)	Revenues by: • Geographic distribution • Customer type	• Space-related workforce (FTEs) • Educational attainment • Age • Gender	Not applicable	Not applicable
State and Health of the European EO Services Industry (EARSC, Europe)	Space-related revenues by: • Sectors • Value chain • Geographic distribution • Customer type	• Space-related workforce • Educational attainment • Gender	Not applicable	Not applicable
Space industry annual survey (Society of Japanese Aerospace Companies)	Revenues by: • Sectors • Geographic distribution • Customer type	• Space-related workforce (headcounts) • Occupations	• R&D expenditure • Patent applications	Not applicable
State of the satellite industry (Satellite Industry Association (SIA), United States)	Revenues	• Space-related workforce (headcounts)	Not applicable	Not applicable

1. These surveys are not specifically targeting space sector enterprises but include some space-related questions.

Section 1: General instructions and definitions

From it beginning the survey should provide clear instructions and practical information for respondents (OECD/Eurostat, 2018[2]). Some basic definitions may be included as well as explanatory notes either in an annex or, in the case of web-based questionnaires, as floating fields. To be user-friendly, it is also useful to mention how long it will take to respond and how many questions are included (even if not all of them may be applicable). Some surveys may be quite short while others may be very long and the respondent may wish to know this in advance.

As an example, the US Department of Commerce's mandatory survey indicated that the "[p]ublic reporting burden for this collection of information is estimated to average 14 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information" (US Department of Commerce, 2013[18]).

Section 2: Respondent information

This section includes information concerning the respondent (organisation and point of contact). As mentioned by all survey developers, it is important to make sure that a point of contact is well-identified and can be contacted if there are issues with responses (e.g. missing information).

Section 3: Revenues

Space sector revenues (often used interchangeably with "sales" and "turnover") refer to the income received from the sale of space goods and services. Revenue is one of the main measures used to track the health and development of the space economy.

Different breakdowns of income need to be captured: Sales versus grants, domestic versus international sales (exports), and public sector revenue versus private sector revenue. Revenues also ideally need to be reported by key activities (e.g. manufacturing, satellite operations) and when possible, by sector of application (e.g. satellite communications, earth observation). Some countries may wish to highlight specific sectors (e.g. meteorology). If broadcasting is of interest, it should be kept as a separate sector of application because of its sheer size (see Chapter 2 for definition of activities). Based on existing examples (e.g. Canada, Germany, United Kingdom, Korea), the model questionnaire in Annex 4.A suggests some questions to facilitate comparisons across countries.

Business enterprises may be involved in major institutional contracts with many of their own suppliers receiving shares of these larger contracts along the value chain. This affects how revenues are accounted for in different enterprises. At the survey level, this may require appropriate consolidation for accurate measurements that avoid inflating the final figures on revenues as demonstrated by the Eurospace methodologies to avoid double-counting (Eurospace, 2021[12]). When surveying different departments in a given business enterprise, special attention should be given to avoid double-counting revenues by mistake.

Section 4: Workforce and skills

This section collects information on the total number of people working in the organisation and those involved in space-related activities. As seen in Chapter 3, there are many ways to measure employment with different metrics useful in different contexts. Questionnaires to support the collection of work and labour market data should be aligned with the latest international standards (International Labour Organisation, 2021[21]). The workforce of certain organisations and facilities (e.g. NASA and ESA centres) may include external contributors (external contractors) that are fully integrated into the organisation's activities without formally being employed by them. The *Frascati Manual* recommends that these external personnel be identified and counted as part of the workforce.

Some of the key metrics to collect include:

- Total workforce and space-related workforce: It is important to indicate the unit of measurement e.g. the number of people employed (headcounts) or full-time equivalents (FTEs). FTE is the ratio of working hours actually spent on an activity during a specific reference period (usually a calendar year) divided by the total number of hours conventionally worked in the same period. If the same person performs two or more tasks, an indication of the weighting of each task in their overall responsibilities would be required. Any potential external personnel/contractor (fully integrated into activities, but not employed by the organisation) should also be counted.
- Space-related workforce, by space activity, when possible, i.e. involved in space exploration, telecommunications, etc. (see model questionnaire in Annex 4.A).
- Type of occupation: Options in this question need to be well defined, ideally using existing national and/or international classifications. As seen in Chapter 3, the *Oslo Manual* encourages the collection of data on occupational status based on the International Labour Organisation Standard Classification of Occupations (ISCO-08) (ILO, 2016[20]). This includes occupations such as "science and engineering professionals", "information and communications technology professionals", and "science and engineering technicians".
- Educational attainment (e.g. secondary school, post-secondary non-tertiary (vocational school) or different levels of tertiary education): International frameworks include the UNESCO Fields of Education and Training (ISCED-F 2013).
- Age and gender of employees: These aspects are useful for tracking specific policy objectives such as gender equality or demographic trends in the space economy.

Section 5: Research and development / Innovation

The OECD provides guidance for collecting data and developing statistics on research and development (R&D) and innovation in the internationally agreed *Frascati Manual* on R&D and the *Oslo Manual* on Innovation (OECD, 2015[1]; OECD/Eurostat, 2018[2]).

Three types of questions should generally appear in this section:

- R&D-related expenditure: A distinction between internally and externally funded R&D could be included depending on the details required.
- R&D workforce: The number of workers engaged in R&D activities preferably in FTEs.
- Innovation: Asking respondents to provide proxy information such as the number of patents awarded.

Section 6: Effects of participation in space programmes

In recent surveys conducted by the Canadian Space Agency, a new section on "return on investment" has been included (Canadian Space Agency, 2020[10]). This section aims to gain a better understanding of the effects of government funded space projects (e.g. increased collaboration, reputational effects, and additional revenues). The nature of the effects will differ depending on the type of organisation that received funding (business enterprises, public research organisation and universities). Several questions can be asked regarding:

- additional revenues (e.g. not the grants/contracts themselves, but estimates of additional revenues generated as a result of programme participation)
- increased visibility and reputation
- improved internal knowledge, skills and capabilities
- partnerships and collaborations with other actors (public/private)
- scientific and innovation outputs (scientific papers, patent applications, innovations).

Concluding the survey: At the end of the questionnaire, it is useful to allow additional comments from respondents. This provides respondents with the opportunity to freely input information they consider to be important to the subject of the survey but missed in the questionnaire.

Key take-aways on space economy surveys

By summarising existing best practices, this chapter has provided some of the key considerations involved in conducting a space economy survey. The following key conclusions on surveys complement remarks made in Chapter 2 (definitions and concepts) and Chapter 3 (actors):

Use standard and well-established practices: This chapter relays the practices and data collection efforts of a selected government organisations and industry associations carrying out space industry surveys, most of which are using standard and well-established practices. While it may be beyond the means of smaller space organisations to carry out large-scale surveys, all economies with a space programme are encouraged to conduct surveys using standard methodologies and then share high-level public results (e.g. aggregated data, space industry demographics). This can provide valuable information and contribute to identifying trends in the broader space economy for the benefit of all.

Partner with other knowledgeable organisation: Partnerships with government agencies, such as national statistical offices and with industry associations, can provide methodological support, added credibility and, in some cases, secure extra funding (particularly when conducting large-scale economic surveys). Collaboration often ensures a more solid and standardised methodological approach and greater outreach and visibility.

There is a strong need for greater international co-operation and co-ordination to improve comparability: Agencies conducting industry surveys highlight the burden of work involved, even when only supervising consultants' work. Greater international co-ordination for developing joint definitions and methodologies is therefore necessary to reduce the burdens associated with survey design. The OECD Space Forum will continue to facilitate exchanges on best practices across a growing number of institutions worldwide.

Annex 4.A. Model survey for measuring the space economy

As discussed in this chapter, all surveys need to be based on specific objectives that are context specific. Despite this, a model survey with some generic sections and questions is proposed here in order to encourage the use of particular generic questions. The questions should be adapted to local context with more or less detail added as required. The questions are largely inspired by existing questionnaires and the lessons learnt shared during OECD Space Forum meetings (Fischer et al., 2021[3]). To facilitate follow-up analysis, the proposed questions presented here should be arranged in matrix format using spreadsheet programmes (e.g. MS Excel and alternatives) and ideally use online solutions.

Respondent information

Contact Information for the survey
Name:
Division/Department:
Email:
Phone:

Organisation name:
Address:
Postcode:
(If applicable, a unique identifier such as a tax reference number may also be requested)

Please specify your organisation type:

- Micro enterprise (<9 employees)
- Small enterprise (10-49 employees)
- Medium enterprise (50-250 employees)
- Large enterprise (>250 employees)
- Higher education institution
- Other research / non-commercial organisation (please specify): …

Is your organisation privately owned or publicly traded?

- Privately owned
- Publicly traded
- Publicly owned
- Not applicable

Is your organisation foreign-owned? If yes, what percentage (from 0% to 100%)?

Is your operating profit consolidated in the earnings of a parent company? Yes/No
If so, please give the name of your parent company: …

Revenues

Please indicate for which fiscal year you are reporting (note; the start of the fiscal year may be different from country to country, often with a start in January or April):

- 2020-2021
- 2021-2022

What is your organisation's total revenue? … (national currency)

What is the share of space-related revenues in your organisation's total revenue? … %

Please estimate a breakdown of space-related income by type:

- Domestic sales: … %
- International sales (exports)
- Grants: …%
- Other (please specify): %

Please give a breakdown of your space-related revenues (domestic and international) by customer type:

- Business enterprises: … %
- Government administrations (list all the names of the main possible customers, e.g. space agency, defence department…): … %
- Higher education institutes (list all the names of the main possible customers, e.g. university X or Y): …%

If you are exporting products and services, please estimate the breakdown by customer location (total should be 100%)

- North America (USA, Canada, Mexico): …%
- Europe …% (European Union …% -- Non-European Union (Norway, Switzerland): …%
- Central and South America (including Caribbean): …%
- Middle East: …%
- Africa: …%
- Asia and Oceania: …%

Please select which space activity your organisation is engaged in:

- Science
- Space exploration (including space stations, rovers and probes)
- Space transportation (including launch)
- Satellite communications (excluding broadcasting)
- Satellite broadcasting
- Positioning, navigation, timing
- Earth observation (excluding meteorology)
- Meteorology
- Other (generic technologies or components, please specify): …

For each space activity you are engaged in, please provide a breakdown of your total space-related revenues by your main products and services (total should add up to 100%). The table could be repeated for each space activity, i.e. space exploration, telecommunications, etc. (see Chapter 2 for definitions).

Share of space-related revenue (%)	Main areas of products and services
	Research, engineering and other services
	Space manufacturing
	Space launch and transportation
	Operations of space and/or ground systems
	Supply of devices and products supporting the consumer markets
	Supply of services supporting the consumer markets

Please indicate if these space-related revenues are fully consolidated (i.e. including intermediate products and services from third parties). Do you track the share of these intermediate products and services in your consolidated revenues?

Workforce and skills

Workforce

Please indicate the number of employees, in [country], working in your organisation in full time equivalent hours, also including externally hired staff. (Full-time equivalent (FTE) is the ratio of working hours actually spent on an activity during a specific reference period (usually a calendar year) divided by the total number of hours conventionally worked in the same period.)

Please estimate the share of employees involved in space-related activities? …%

Please indicate the total number of people employed in your organisation by job function and indicate the share of employees in space-related activities and the share that are female.

Functions	Total number of employees	% of female employees	% of employees involved in space-related activities
Management			
Engineers and scientists			
Technicians			
Marketing and sales			
Administration			
Students/interns			

Over the last year, has your organisation experienced challenges recruiting qualified workers to the extent that positions remained vacant? Yes/No

Please select the occupations for which your company has experienced challenges recruiting qualified workers to the extent that positions remained vacant (e.g. management, engineers and scientists, technicians, marketing and sales, administration, students/Interns).

Skills

Please estimate the percentage breakdown of employees by the highest qualification obtained in the most recent year available (total 100%)

- PhD or above: …%
- Master’s degree: …%
- Bachelor’s degree: …%
- Vocational qualification: …%
- Other qualification …%

Research, development and innovation

Research and development

Could you provide your organisation’s total expenditure on R&D? …

Could you estimate the share of your organisation’s total expenditure on R&D for space activities? …%

How many people are employed in R&D activities and working the equivalent of full-time hours? …

What is the share of people involved in space-related R&D and working the equivalent of full-time hours? …%

Inventions

Please indicate the number of space-related inventions you have produced this year (protected or not): …

Please indicate the share of space-related patents you have registered this year: …

If applicable, please indicate the number of space-related technology licenses you have received this year: …

Innovation

Innovation in space products/services: A product innovation is a new or improved good or service that differs significantly from the firm's previous goods or services and which has been implemented on the market. It includes significant changes to the design of a product, or digital products or services. It excludes the simple re-sale of new goods and changes of a solely aesthetic nature.

Please indicate if you have introduced any new or improved space products this year? Yes/No

Please indicate if you have introduced any new or improved space services this year? Yes/No

Innovation in business processes: A business process innovation is a new or improved business process for one or more business functions that differs significantly from the firm's previous business processes and that has been brought into use in the firm.

Please indicate if you have introduced any of the following types of new or improved processes that differ significantly from your previous processes this year:

- Methods for producing space products or providing services (including methods for developing products or services)? Yes/No
- Logistics, delivery or distribution methods? Yes/No
- Methods for information processing or communication? Yes/No
- Methods for accounting or other administrative operations? Yes/No
- Business practices for organising procedures or external relations? Yes/No
- Methods of organising work responsibility, decision making or human resource management? Yes/No
- Marketing methods for promotion, packaging, pricing, product placement or after sales services? Yes/No

Effects of participation in space programmes

Has your organisation received grants from a governmental institution in the past? Yes/No

Please describe: …

Has the project generated reputation effects (new contracts, new clients, etc.)? Yes/No

Please provide details: …

Have you attempted to generate revenues from the product, application or service developed for the project, beyond the value of the original project (i.e. commercialisation)? Yes/No

Are you planning to use a product, application or service developed for the project to generate revenues from sales to customers that are not specified in the project contracts? Yes/No

If the product, application or service developed for the project was re-used in other space projects, please indicate the total revenue received over the last year: …

If the product, application or service developed for the space project was adapted for use in areas of the economy not related space, please indicate the total revenue received over the last year: …

<u>Final section</u>

Possible evolutions of your organisation:

Compared to performance in the last three years, please estimate how your organisation is likely to perform over the next three years. Please comment on factors influencing your projections:

	Much lower	Lower	Same	Higher	Much higher	Not applicable
Revenue						
Export (if applicable)						
Employment						
R&D expenditure						
Overall investment						

Further contact

Would you accept to be contacted via email to take part in further engagement hosted by xxx (the surveyor) and for your information to be shared for this purpose? Yes/No

Should you wish to make any other comments concerning this survey, please feel free: …

End of the Model Questionnaire

Annex 4.B. Launching and conducting a space industry survey: Lessons learnt from CSA-DLR co-operation

Canada and Germany are two active members of the OECD Space Forum that collaborated closely on space economy surveys in 2020 and 2021. They kindly agreed to share their experience in this *Handbook*, with a systematic approach and practical recommendations for actors wishing to develop their own survey (Fischer et al., 2021[3]).

The Canadian Space Agency (CSA) has considerable experience in managing its national space industry survey and using the results to guide policymaking. The German Space Agency (DLR) used in 2020-21 very similar questions to those in the CSA survey. Enhancing international comparability of results is challenging, as survey design has to be considered, from how the target population is selected to the sampling methodology, through to the procedures followed to process the results. Still asking similar questions is a step in the right direction.

Based on exchanges in several OECD Space Forum meetings, and on the recent Canadian and German experiences, the lessons learnt from the experts in the CSA and the DLR are provided below and are referenced throughout Chapter 4 on industry surveys. The authors, Hendrik Fischer and Mara Grunewald from the DLR; and David Haight; Aaron Parsons; and James Jarvis-Thiébault from the CSA, are kindly thanked for their useful inputs.

Organisational requirements for launching a space industry survey

The resources, time, and effort required for the survey are determined by its scope. Members of the OECD Space Forum have suggested that a team of two-three people are needed at various times throughout the process, with at least one staff member dedicated to maintaining the survey and contact list for a sample size of 150-250 organisations.

Where to begin

It is recommended that before beginning the process of establishing a survey, consultation with national statistics agencies, other government departments, and the OECD Space Forum be conducted to learn of available public sources of information and to establish parameters for the survey.

- Additionally, national statistics repositories may contain information sought for the survey, alleviating the need to ask these questions and limiting response burden on survey participants.

Establishing a target audience, which may include industry, academia (universities, colleges, and technical institutes), associations, non-profit groups, research institutes, etc., will determine how broad or targeted the survey will be.

- It is recommended that space organisations begin the outreach to a target audience through existing relationships and known actors in the space community.

Survey methodology

The following guidelines are not exhaustive, but will provide vital information and processes to ensure a better outcome for the intended survey:

- Presumably, the survey to be administered will be voluntary and proponents should therefore be aware of limitations associated with voluntary surveys.
- The length of the survey and the response burden on participants should guide development.
- Language should be clear and simple, minimising misinterpretation and inaccuracy in survey responses.
- Information should not be collected unless it has an intended utility. Therefore, it is important to ensure that the questions being asked are relevant to the indicators you wish to measure.
- Determine the type of information you intend to collect. Given the focus on socio-economic measurements, it is assumed the majority of indicators are quantitative (revenues, employment, R&D spending etc.), but the value of qualitative data should not be dismissed, and consideration for qualitative impacts should be considered as well.
- Run a preliminary test of your questionnaire with one or two companies or organisations that are well known to you. This way, misunderstandings and imprecise formulations can be avoided in advance.
- It is recommended that a "feedback" section be added to each survey to allow participants to voice concerns, technical issues, clarifications, and suggest improvements to the survey. This type of information is valuable for improving measurements and the posing of questions.
- Lessons learnt through administration of space sector surveys over time have also suggested that a willingness to adjust the survey based on needs and input is useful, and that continual refinement over time is essential to maintain relevance and consistency.
- Prior to reaching out to organisations, it is important that a contact list be developed not only with the names and contact information of organisations, but with key points of contact that will actually respond to the survey. The contact list will require constant updates and maintenance to ensure its accuracy and utility.
- Categorisations for data collected can be further informed by this *OECD Handbook on Measuring the Space Economy*. The report contains further details on space value-chain classifications, as well as methods for utilising industrial classifications (see Chapters 2 and 3).

Logistical issues

Prior to discussing the survey on the phone with the organisation, an outreach strategy should be developed. The strategy should include a standardised introduction to the head of the organisation (president, CEO, etc.), description of the survey and its utility, as well as a request for the organisation to identify a key point of contact who will respond to the survey.

This process is important for communicating the importance of the survey and establishing a point of contact.

- In addition, building a positive relationship at the outset will help ensure a high response rate.

It is recommended to use a single email address for all email communication related to the survey. In this way the organisation has a standard method of contacting the survey administrator should there be any issues.

- When launching the survey, an initial invitation to the president/CEO (from the head of the entity administering the survey) alerts them that the survey has launched.

- Subsequently, an email containing an individualised hyperlink to the survey should be sent to the survey contact that will complete the survey on behalf of the organisation.
- Reminder emails should be distributed two weeks prior to the survey deadline to encourage participation.
- When the survey is complete, a thank you email with a link to the report should be distributed to survey participants.

To mitigate the risk of a low response rate, it is encouraged to call organisations two weeks prior to the survey deadline as a reminder with a particular focus on key organisations.

- Phone calls are the most efficient method of encouraging organisations to participate.
- Personalised emails are a useful supplementary method of encouraging participation.

To increase the informative value of the survey data even in the event of low response rates, focus particularly on the big players, who generate the lion's share of employees and sales. If the ten largest companies or research institutes do not provide accurate data, the informative value of the survey would be severely limited. To mitigate the risk of a low response rate, it is encouraged to call organisations two weeks prior to the survey deadline as a reminder with a particular focus on key organisations.

- Spend enough time in convincing the big players to participate and to identify the right contact person within their organisations.
- Additional reminders by phone calls are useful.

Data collection and storage

A system for distributing the survey in a confidential manner is recommended, such as an email invitation containing individualised hyperlinks to a secure survey web address.

- Data collected in this manner are more secure and easier to collate than administering forms through email.
- A centralised system for collecting the data makes it more easily retrievable for analysis once the survey has closed.

Conclusion

Conducting a survey and subsequent publication of space sector data (in aggregate) has significant utility as a domestic communication tool, and allows for international comparisons, trend assessments, and informs government decisions on policies and programming for the space sector.

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5 Strengthening assessment of the impacts of the space economy

The number and quality of indicators measuring the socio-economic effects of space activities have grown over the years, but challenges remain in achieving comparability and linking back to overlying policy objectives. This chapter addresses some of these issues by clarifying current terminology based on the evaluation literature, reviewing selected examples of indicators and identifying potential future needs.

Introduction

Public expenditures on space programmes are often justified by the capabilities and improvements they bring in the provision of public services, national security, and government-led scientific services (e.g. meteorology and environmental monitoring). Furthermore, applications that rely on satellite data and signals drive efficiency savings across a broad range of activities and help to create new commercial markets (OECD, 2021[1]). The space economy is therefore increasingly seen as a possible driver of future prosperity.

The term *impact assessment* describes a set of analytical tools used to understand the negative and positive effects of a particular policy so that the resulting impact can be evaluated. Impact assessments assist public policymakers in demonstrating the socio-economic effects of space activities but are also used in private sector decision taking. They may be performed *ex ante* to assist policymakers and decision makers by exploring the range of potential future effects of a policy decision and the magnitude and direction of their likely impacts. They may also be conducted *ex post* to provide a measure of the success or failure of interventions already implemented.

The OECD Space Forum has identified multiple space economy evaluations and impact assessments that have been conducted over the past two decades in OECD member countries and partner economies (see Annex Table 5.A.1 for a selection of studies). Many areas of the space economy have been subject to such analysis and some areas have been focused on multiple times in different contexts.

Past studies have been conducted on the impacts of:

- entire national space programmes, as conducted in e.g. Canada, Denmark, India, Norway and the United Kingdom
- specific sets of applications or activities, e.g. earth observation, space exploration, launchers, as conducted in organisations in e.g. Europe, United States and Australia
- specific programmes, e.g. Landsat in the United States or Eumetsat's EPS/Metop 2 programmes
- government facilities, e.g. National Aeronautics and Space Administration (NASA) and European Space Agency (ESA) centres.

The number and types of recorded effects and estimated impacts of space activities have therefore grown substantially in recent years. However, challenges remain in producing findings that are reproducible over time, comparable with other areas of the economy and across countries. More effort also needs to be devoted to assessing both the positive and negative effects of space policy implementation.

This chapter aims to address some of these issues by clarifying the terminology adopted in the field of impact assessment, discussing the effects of the space economy on society, introducing how such effects may be measured and identifying potential future needs for conducting effective analyses.

Brief introduction to assessing impact

The variety of statistics on space activities is broader than ever before (OECD, 2020[2]). The indicators constructed from them provide information that may be used to monitor the performance of space activities across a range of measures of interest to space economy analysts. However, understanding the societal value of the space economy requires frameworks used to estimate the magnitude of and compare both the positive and negative effects of space activities. This section describes the vocabulary used and the methodologies employed internationally that allow for assessments of impact to be conducted and repeated over time.

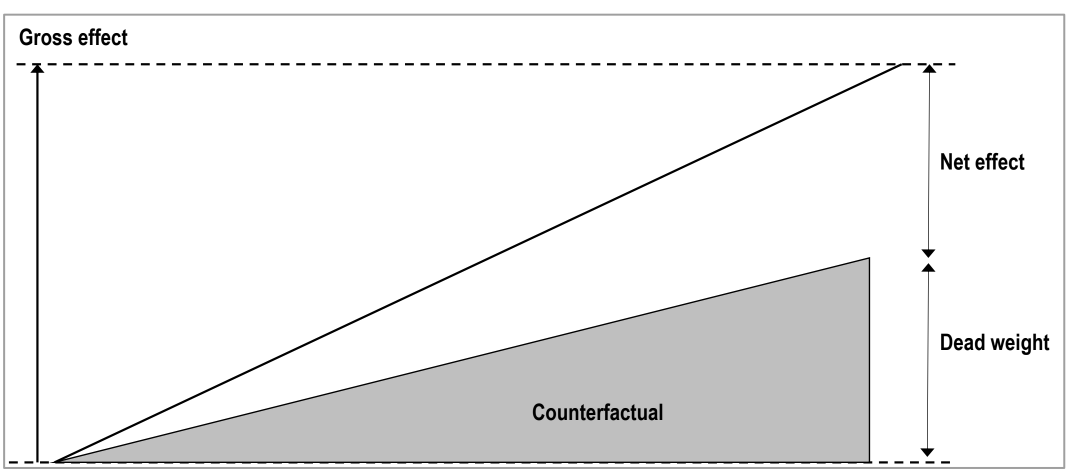
Terminology of impact assessment

When conducting evaluations of the space economy, terms such as "'outputs", "outcomes" and "impacts" are often used interchangeably, and tend to overlap (see OECD (2021[3])). The following standard definitions can be found in the literature:

- Outputs refer to what is produced directly or immediately by an activity. Depending on their nature, outputs may or may not be straightforward to measure. Outputs may for example refer to the goods or services produced by government agencies, or the private sector measured in quantities produced, the goods and services produced by the space business enterprise sector measured in total revenues, the number of scientific papers in refereed journals, or the number of annual space launches.
- Outcomes refer to the effects that are ultimately achieved by an activity, positive and negative, intended and unintended. In other words, they are defined as the effects arising from the delivery of outputs on social, economic, environmental or other important areas.
- Impacts refer to the much broader results of achieving the ultimate goals of a programme or policy, taking into account the positive and negative effects, as well as the intended and unintended effects. For example, the contribution of public spending on the space economy in improving the economic performance of broader areas of the overall economy, once all other potential contributions to economic performance in those areas have been controlled for.

Measuring impacts is complex, as an exhaustive analysis of the effects of a particular policy or decision requires taking into account what could have happened in the absence of the policy or decision having taken place. This requires accurate attribution of effects to a given action, estimates of the extent to which an action may have displaced other potential positive outcomes and a clear understanding of the negative consequences (whether intentional and mitigated against or unintended and unmitigated) (OECD, 2015[4]). In the evaluation literature, causal impacts refer to the "difference between potential outcomes under observed and unobserved counterfactual treatments" (OECD/Eurostat, 2018[5]). In this chapter, the term "effect" will encompass both outcomes and impacts to take into account the overlaps (Figure 5.1).

Figure 5.1. Gross and net effects



Source: OECD (2015[4]), "Causality problems", https://www.oecd.org/sti/inno/What-is-impact-assessment-OECDImpact.pdf.

Dealing with effects that are difficult to quantify

In many cases, it can be difficult to express the effects of space activities in quantitative units. Earth observation, national security applications, space exploration and science, for example, are all associated with considerable intangible social and strategic benefits. Examples include:

- The advancement of technology and knowledge: This includes breakthrough missions, from the European Space Agency's Rosetta mission to Comet 67P/Churyumov-Gerasimenko to the first images of Pluto (NASA's New Horizons).
- Culture and inspiration: The Moon landing is one of the most iconic events of the 20th century and is thought to have inspired an entire generation of scientists.
- International partnerships and means to address global challenges: The space sector is characterised by high levels of international co-operation, illustrated by the International Space Station, the co-ordination of meteorological missions or the development and provision of instruments on exploration missions (OECD, 2014[6]). One of the first emblematic joint space missions took place in 1975 during the Cold War, when an American spacecraft docked for the first time with a Russian spacecraft. In addition to the political significance of the event, it was a major engineering accomplishment, as both the US and the Russian systems relied on domestic hardware and standards.
- Space-based systems provide significant military capabilities: both in terms of tactical weapons and providing operative support.

Effects that are difficult to quantify are often highlighted as qualitative case studies. Certain impact assessment methodologies may be better suited to evaluating qualitative effects than others. Multi-criteria analysis, for example, has been used to score the significance of different types of effects including those that are not quantified. A 2019 application of this method in an assessment of ESA's science programmes identified important effects across scientific, social, economic and strategic areas in education, international cooperation, scientific production and quality, scientific interest, inspiration and awareness (PwC, 2019[7]).

Due to the broadly intangible nature of many of the effects associated with it, a substantial share of space economy impact assessments relies on hybrid or partial approaches. The estimated effects tend to be based on a combination of survey data, ad hoc data collection, interviews and expert opinions. The reasons for this fall into a couple of categories. Firstly, there is a lack of easily accessible and distinct economic statistics on the space economy with space activities dispersed in multiple, aggregated statistical categories of economic activities (Chapter 2). Secondly, as already mentioned, the nature of several of the most important effects of the space economy make them difficult to incorporate in quantitative frameworks as they do not relate to goods and services traded in markets.

Methodologies for evaluating positive and negative effects

Chapter 4 discussed space economy surveys, which may provide data to quantify the positive effects of space activities such as business enterprise revenues and employment, investment in space infrastructure and new science and technology. Impact assessment involves comparing positive effects such as these with any potential negative ones. A number of standard methodologies exist to identify and compare realised or potential effects and the overall impacts of future or past policy interventions.

Table 5.1 lists some of the most common approaches to assessing impact.

Table 5.1. Methodologies used in impact assessments and examples from evaluations of the space economy

Methodology	Description	Indicators	Examples in the space sector
Cost benefit analysis (CBA)	Cost benefit analyses quantify benefits and costs in monetary terms and compare them over time. Results are compared to a counterfactual "do-nothing" scenario.	Monetised benefits and costs, including intended and unintended economic, social and environmental effects.	CBAs have been used in ex ante evaluations, like the impact study for the global monitoring for environment and security programme (GMES, currently Copernicus) (Booz & Company, 2011[8]); the use of satellite imagery for safeguard tasks at the International Atomic Energy Agency (IAEA) (Andersson, 1999[9]); and the case for a second generation of the EPS/MetOP weather satellites (EUMETSAT, 2014[10]). India has also conducted a CBA of its space programme (Sridhara Murthi, Sankar and Madhusudhan, 2007[11]). A major Italian CBA highlights the role of public policies in the space sector (Università di Milano and Agenzia Spaziale Italiana, 2021[12]).
Cost effectiveness analysis and cost utility analysis	A variety of cost benefit analysis, cost effectiveness analyses take the benefits of the intervention as a given and compares different policy options.	Cost effectiveness ratios, e.g. quality-adjusted life years (QUALYs) and disability-adjusted life years (DALYs).	Few examples are available in the literature for space activities. Perhaps the most prominent cost-effectiveness analysis in the space sector is the feasibility study of the Space Shuttle System (Mathematica, 1972[13]).
Input-output modelling	Input-output models trace the activity generated by a project or intervention in other parts of the economy. Common models: IMPLAN and RIMS-II.	GDP and employment multipliers, comprising direct, indirect and induced effects; contributions to GDP, employment and government revenues.	Economic impact analyses are frequently used to study the impacts of space programmes on employment and other economic activities in the whole economy. They are particularly common in North America, where the space manufacturing and launch activities have distinct industrial classification (NAICS) codes. Examples include (FAA, 2008[14]; Goss Gilroy Inc., 2010[15]; CSA, 2019[16]; PwC, 2014[17]; London Economics, 2015[18]; Florida Tech, 2022[19]).
General equilibrium modelling	More dynamic and complex than input-output modelling. Simulations are run to assess the impacts of different policy options on the economy. Examples of models applied in the space sector: E3ME (Europe) and Tasman Global (Australia).	GDP and employment multipliers; contributions to GDP, employment, government revenues, productivity, pollution, etc.	Examples include (Eftec, 2013[20]) for determining satellite telecommunications' contributions to sustainable development; (PwC, 2019[21]) for assessing socio-economic benefits of selected ESA earth observation activities; and for computing the value of earth observations and augmented GNSS in Australia (ACIL Allen, 2015[22]; 2013[23]).
Multi-criteria analysis	Multi-criteria analysis allows systematic decisions to be made in cases where quantification of impacts is difficult.	Effects of policy options receive weighted scores according to predetermined criteria. And options are ranked according to their final score.	Recent examples include (PwC, 2019[7]; Euroconsult, 2019[24]) for the socio-economic assessments of ESA's science programme and communication satellites for safety and security.

Selected effects and approaches to their measurement

This section outlines the rationale for studying the impact of the space economy and summarises approaches to their evaluation. It focuses on the analysis of four categories of effects and methods that are generally considered in impact assessments of the space economy. The first considers the effects of space programmes on organisations operating in the space economy, the performance of which is increasingly used as a justification for public expenditure on space programmes. The second relates to the economic value generated by space activities and their linkages with activities in the rest of the economy based on input-output analysis. The third focuses specifically on the effects of technology originally developed by space activities and subsequently transferred into other areas of the economy. And the fourth explores burgeoning efforts to understand the role and value of satellite-derived information products on society as a whole.

The effects of participation in space programmes on organisations' performance

A growing number of studies evaluate the effects of government space programmes on participating organisations and their performance, in terms of knowledge, networks, revenues, academic reputation, etc.

Space programmes are often evaluated in terms of their impact on research. A qualitative study of the effects of Norwegian participation in European Space Agency Science projects suggests that involvement led to increased experience, knowledge and contacts. In turn, these improvements enabled participation in new projects, better international recognition (supported by scientific publications in prestigious journals, grants and awards) and furthered knowledge transfers to other projects and activities (Høegh Berdal, 2018[25]). The report asserts that participation in ESA science projects has been essential in shaping the solar physics scientific community in Norway as it is today, for example. More broadly, a 2019 assessment of eight ESA science missions (four past missions: XMM-Newton, Rosetta, SOHO, and the participation of ESA to the Hubble Space Telescope (HST); and four future missions, i.e., JUICE, ARIEL, SMILE and the participation of ESA to the James Webb Space Telescope (JWST)) found strong effects in terms of scientific quality and international collaboration (PwC, 2019[7]).

The effects of space programme participation are felt beyond research. An evaluation of Swiss R&D funding instruments for space activities considered both higher education institutes and business enterprises (Barjak, Bill and Samuel, 2015[26]). The survey results reveal that more than 80% of the academic respondents assessed ESA projects and complementary national activities as contributing positively to academic reputation, the size of the global academic network, employees' competencies, and the recruitment and training of staff (Figure 5.2). But, in addition, around 60% of respondents representing business enterprises reported that participation had led to better outcomes across a range of business metrics including quantity of products sold and diversification of clients and markets.

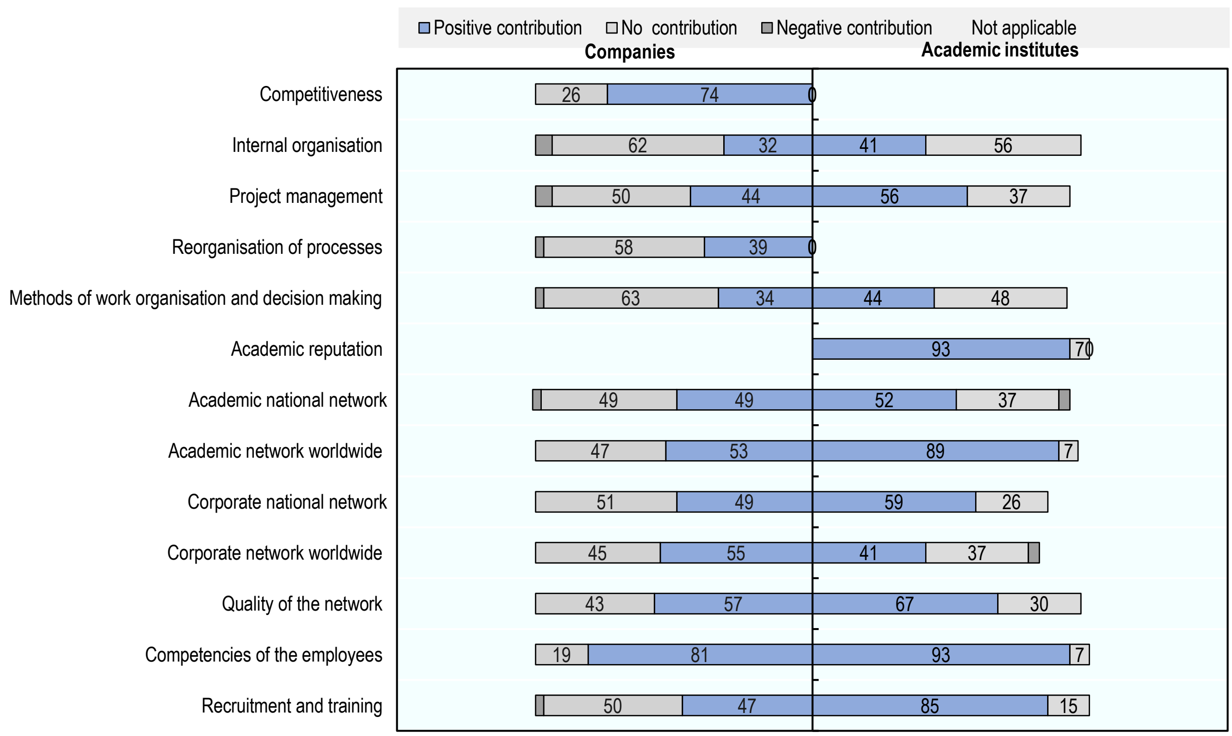
In OECD countries, space programmes have always sought the involvement of organisations operating in sectors beyond the government and higher education sectors, with a particular focus on the participation of business enterprises. The motivations for and expected outcomes from the participation of business enterprises in space programmes have been described in multiple previous analyses. A study from the early 1990s of firms participating in ESA projects, for example, outlined multiple positive effects including: better access to new markets, effective technological and scientific networks, the development of more capable staff and more advanced managerial expertise (BETA, 1991[27]). The Norwegian study outlined above found that firms receiving contracts associated with ESA Science programmes reported significant technological effects and the opening of new market opportunities (Høegh Berdal, 2018[25]).

Assessing the impacts of space programmes on business enterprise activity often involves tracking and quantifying the positive effects and contrasting them with likely outcomes in absence of the space programme. A core objective of impact assessments of this type is to capture and quantify technological, reputational, networking and other spillovers from space programme participation on the business performance of organisations from any sector. Frequently, some measure of output is used as a proxy for the combined influence of all of the above effects. A common approach is to estimate *additional revenues* attributable to participation in the space programme.

The section below considers first the effects of space programme participation on firms operating primarily in the business enterprise sector. It then focuses on the effects of participation on the business enterprise activity of organisations operating primarily in the higher education sector, and finally ends with a few examples of the potential negative effects of space programmes overall.

Figure 5.2. Organisation-related outcomes of ESA projects and complementary national activities by sector in Switzerland

Share of respondents (%)



Note: Academic institutes: n≥ 22, companies: n≥ 34.

Source: Based on Barjak, Bill and Samuel (2015[26]), "Evaluation of the existing Swiss institutional R&D funding instruments for the implementation of the space-related measures", https://www.sbfi.admin.ch/dam/sbfi/fr/dokumente/evaluation_of_theexistingswissinstitutionalrdfundinginstruments.pdf.download.pdf/evaluation_of_theexistingswissinstitutionalrdfundinginstruments.pdf.

Effects on firms operating primarily in the business enterprise sector

Several members of the European Space Agency (ESA) have conducted assessments of their domestic firms' participation in ESA programmes. Examples exist from Norway (Norwegian Space Agency, 2018[28]), Denmark (Ramboll Management Consulting, 2008[29]) Portugal (Clama Consulting, 2011[30]) and the United Kingdom (Technopolis, 2019[31]; London Economics, 2018[32]) to name a few. The data used in such analyses are mostly collected from the business enterprise sector through surveys and interviews, where firms self-assess the additional revenues resulting from space programme participation.

Several sources of additional revenues are identified and made explicit in these studies, mainly resulting from technology and expertise developed through the realisation of contracts awarded through government space programmes. Examples include additional revenues from existing products that would not have been sold without participation, revenues from new products that would not have existed without participation, revenues generated from network or reputation effects caused by participation, and the revenues in firms producing intermediate inputs for those participating.

An alternative approach to collecting self-reported information on additional revenues from firms is to compare enterprises awarded contracts through space programmes with those that are not involved but produce similar goods and services. Multiple assumptions are required for this comparison to hold true that are unlikely to be reflected in reality. A major simplifying assumption is that firms in the two groups have similar characteristics and capabilities on average, a constraint that is unlikely to hold under scrutiny and may lead to inaccurate results.

Finally, an evaluation survey of the United Kingdom's funding of space activities through ESA's programme of Advanced Research in Telecommunications Systems (ARTES) programme found that participation in the programme led to new and strengthened partnerships, new and improved skills, knowledge and capabilities and increased visibility and reputation of UK capabilities (Technopolis, 2019[31]). As a result, 56% of respondents reported that their organisations were generating additional revenues attributable to participation in the ARTES programme and a further 29% reported the expectation of generating additional revenues in the succeeding years. Only 13% of survey respondents expected no additional income from participation in the programme.

Effects on the business enterprise activity of organisations operating primarily in the higher education sector

Business activity is not restricted to firms that operate solely in the business enterprise sector, as seen in Chapter 3. The effect of participation in space programmes on activities of organisations in the higher education sector has also been studied in evaluations.

Take, for example, the involvement of Cardiff University in Wales, United Kingdom, with the Herschel Space Observatory. The Herschel SPIRE project was an ESA-funded astronomical satellite that launched in 2009 and operated until 2013 with Cardiff University leading a consortium of 18 institutions. Cardiff University is primarily a higher education institute that also conducts business enterprise activity, either through research performed under commercial contracts or through the incubation and spinning-off of new businesses. The effects of participation in the Hershel SPIRE project have been shown to be relevant to the activities conducted by Cardiff University in both sectors in which it operates. In addition to the enhanced scientific reputation brought about by leading a major space programme project, the university generated positive effects to its business enterprise activity through the development of three spin-off firms and new follow-on contracts with its commercial partner Airbus valued at GBP 4 million (Sadlier, Farooq and Romain, 2018[33]).

Potential negative effects of space programmes

Space programmes for the most part are funded through government spending and some of this expenditure flows towards the business enterprise sector. As previously noted in Chapter 3, government grants and procurement sometimes represent the main source of income for certain industry segments, e.g. in 2018, sales to the government sector accounted for 57% of the total revenue of the upstream segment in Canada and 71% in Europe (Eurospace, 2020[34]; CSA, 2019[16]). And, as outlined above, business enterprise participation in space programmes has been shown to result in positive effects beyond sales for the business enterprises involved.

Assessment of the impact of public expenditure requires an understanding of both the positive and negative effects of a particular intervention so that the two can be compared. But the potential negative effects of space programmes on the business enterprise sector overall and/or on society as a whole are rarely discussed in evaluations of the space economy. Such negative effects may include, but are not limited to, the unintentional "crowding-out" of business enterprise activity that would exist without public intervention and the potential for public resources to be misallocated. Consider, for example, the effects on the terrestrial telecommunications industry, resulting from the development of satellite communication technologies and public expenditure on their development. While the overall societal impact of satellite communications is considered to be positive, it does not necessarily come without negative effects such as unemployment and economic decline in competing activities.

An increasingly pressing example of the unintended consequences of space programmes relates to space debris and its potential effects on the provision of satellite data (Undseth, Jolly and Olivari, 2020[36]). Much of the activity associated with space programmes since their commencement in the 1950s has involved the deployment of satellites and other instruments into orbit. Satellites have many uses and have important applications in society (see the section: The societal effects of information generated from satellite data*)* for a discussion on one such use case). Due to dramatic reductions in the costs of launching and operating satellites and to the benefits associated with their use, organisations from all sectors of the space economy and in many countries are targeting the deployment of ever-increasing numbers of satellites in low-earth orbit. However, this does not come without risk.

Space debris refers to manmade objects, fragments and elements that result from space operations, ranging from specks of paint and lens caps to rocket bodies and other large objects. Atmospheric drag and other natural phenomena eventually pull debris closer to Earth where they burn up upon entering the atmosphere, but this can take anything from a couple of years to several centuries. There is no atmospheric drag in geostationary orbit, so debris remain there unless moved to dedicated “graveyard” orbits. The accumulation of space debris is a growing problem following several fragmentation events and increased launch activity to the low-earth orbit. In a worst-case scenario, a self-generating cascade of on-orbit collisions could lead to the disruption or loss of certain low-earth orbits (the so-called Kessler syndrome). The costs to society of such an event would likely be very large given the combined value of the positive effects associated with the use of satellites (OECD, 2020[37]). But little attention has been focused on maintaining the sustainability of satellite operations in the environment in which satellites are placed.

Current launch activity to critical orbits is dominated by the business enterprise sector. Mega-constellations of satellites are planned for low orbits including, for example, the OneWeb constellation or SpaceX’s Starlink telecommunications project. The objectives of such commercial activity are to provide internet access to places where connection to ground networks is prohibitively expensive. This is likely to have substantial positive effects. But, no matter how large space is, increasing numbers of satellites and space debris will increase the likelihood of collisions and other risks from occurring (IADC, 2013[37]; Liou, Johnson and Hill, 2010[38]; Boley and Byers, 2021[39]).

The unintended negative effects of space programmes are rarely treated in space economy impact assessments. Data on orbital debris (see Figure 5.3) and information on compliance with debris guidelines and regulations are collected by civil and military space organisations alike (the US Space Force Space-Track website, ESA’s Annual Space Environment Report (ESA, 2021[40]) and NASA’s Orbital Debris Quarterly News (NASA, 2022[41]), for example). But the datasets required to conduct effective assessments are rarely made publicly available. Perhaps because of this, the negative effects of space debris were identified in only one study of the space economy referenced in this chapter (Eftec, 2013[20]).

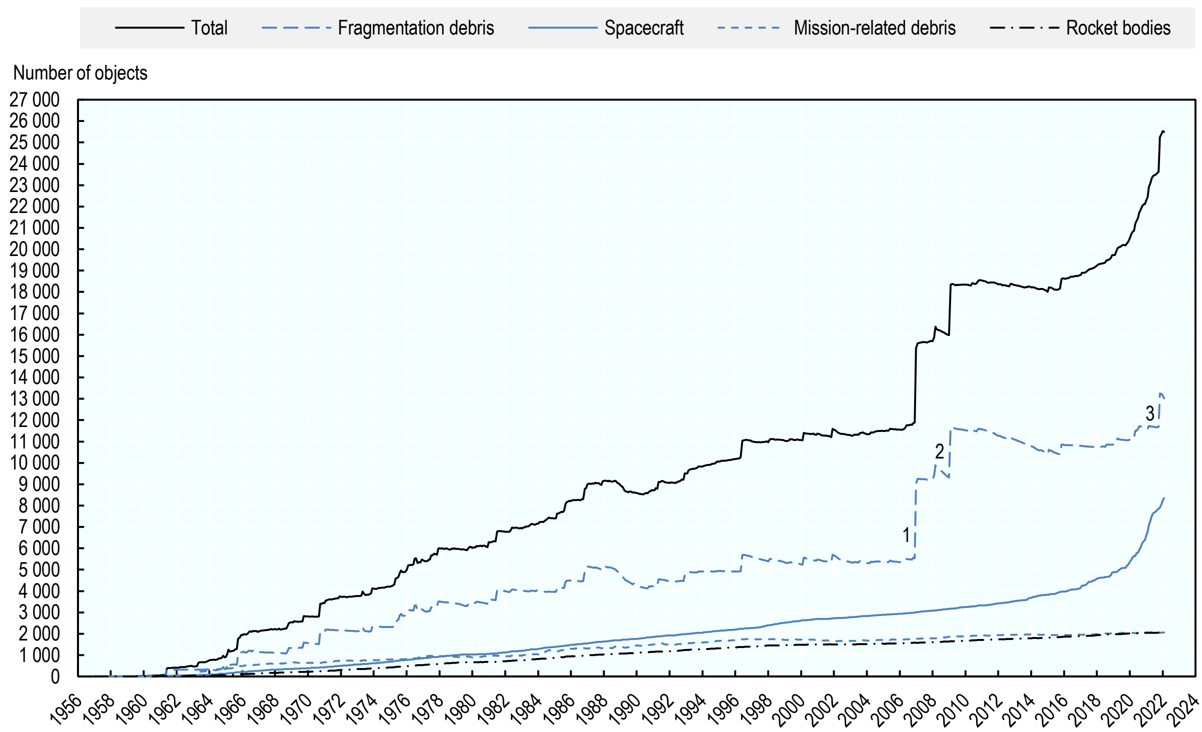
The direct, indirect and induced economic effects of space activities in the general economy

In order to measure the economic effects of space activities in the context of the broader economy, analysts may use a framework known as input-output (IO) analysis. IO analysis is based on the input-output tables (IOTs) that are often, but not exclusively, produced by national statistical offices (OECD, 2021[3]).

Official IOTs are derived from the supply-use tables (SUTs) used in national accounting to measure gross domestic product (GDP) in a robust manner. They represent a transformation of the activity by product nature of the SUTs into an activity by activity or product by product set of analytical tables. In doing so, it is possible to see the effects that particular changes in one part of the economy have on others. An increase in output in Industry X will require an increase in the outputs of all industries that produce goods and services used as intermediate inputs in Industry X and so on. As a result, IO analysis is often used to understand the importance of interrelationships between particular activities and the rest of the economy.

Figure 5.3. The number of space debris objects has accelerated since 2007, potentially threatening the provision of satellite data and signals

Historical increase of the catalogued objects based on data available on 1 March 2022



Notes: The three upward jumps in fragmentation debris correspond to (1) the anti-satellite test conducted the People's Republic of China in 2007, (2) the accidental collision between Iridium 33 and Cosmos 2251 in 2009, and (3) the anti-satellite test conducted by the Russian Federation in November 2021. More Cosmos 1408 fragments are expected to the added to the catalogue in the coming weeks and months.
Source: NASA (2022[41]), *Orbital Debris Quarterly News*, https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/ODQNv26i1.pdf.

IO analysis is a useful tool upon which to estimate the value of the economic effects of a policy intervention and to use as the basis for economic impact assessment. A space economy IO analyst might, for example, consider the effects of the output generated by space activities on the output of economic activities in the rest of the economy.

Economic effects in input-output analysis are frequently broken down into three categories:

- In a study that considers the value to the overall economy of the output generated by the space economy, *direct effects* represent the value of the goods and services produced by the organisations conducting space activities.
- To produce their output, such organisations will require and purchase intermediate inputs. The value of the intermediate goods and services required by space activities are known as *indirect effects*.
- Finally, any production requires a supply of labour which is rewarded through wages and salaries. The subsequent value generated through the sales of goods and services paid for from income earned both directly and indirectly from space activities are called *induced effects*.

The total economic value of a particular policy intervention is therefore the aggregate of the direct, indirect and induced economic effects. It is, however, not necessary to take into account induced economic effects.

In the Netherlands, input-output analysis has been carried for activities in the space economy without including the broader effects on production via wages and salaries (Dialogic and Decisio, 2016[42]).

Space economy input-output analysis in practice

The Canadian Space Agency (CSA) has, in co-operation with Innovation, Science and Economic Development (ISED) Canada, developed a methodology to estimate the indirect and induced effects of production in the space economy using input-output (IO) analysis.

The analysis relies upon official statistics and IO tables constructed by Statistics Canada. As the statistics produced by Statistics Canada are often too aggregated for space activities to be visible, a series of weightings are applied in order to approximate the space-related components in isolation from the rest. The weightings are based on the share of employment in space activities – ascertained from an annual CSA survey of space economy organisations (CSA, 2022[43]) – and in the categories recognised by Statistics Canada (which are based on the NAICS statistical classification). A similar process is used to approximate the magnitude of the interrelationships between space activities and the rest using Statistics Canada's input-output tables.

The results of CSA's 2019 economic impact assessment suggest that Canadian space activities directly employ 10 541 jobs to produce CAD 1.30 billion worth of goods and services. From the industries that supply space activities with intermediate inputs, the IO estimates suggest that Canadian space activities demand CAD 0.60 billion worth of output. In turn, the organisations providing intermediate inputs to Canadian space activities support an additional 6 482 jobs. The people employed in these jobs, both those directly and indirectly supported by Canadian space activities, consume CAD 0.57 billion worth of goods and services in the economy overall. This household spending supports 5 856 further jobs. The total estimated output effect of Canadian space activities is therefore CAD 2.5 billion and the total estimated employment effect is 20 891 jobs (Table 5.2). The advantage of this analysis is that it relies on official statistics augmented by information gathered by the long-standing annual Canadian Space Agency survey.

Table 5.2. Economic impact of space activities in Canada, 2019

Indicator	Direct impact (space sector)	Indirect impact (supply industry)	Induced impact (consumer spending by employees)	Total size of effects	Multiplier
Value of final goods and services	CAD 1.3 billion	CAD 0.6 billion	CAD 0.57 billion	CAD 2.5 billion	1.90
Employment	10 541 jobs	6 482 jobs	5 856 jobs	22 879 jobs	2.17

Source: Canadian Space Agency (2022[43]), "The state of the Canadian space sector 2019", https://www.asc-csa.gc.ca/eng/publications/2020-state-canadian-space-sector-facts-figures-2019.asp#annex-b.

Input-output analysis frameworks are also regularly used to estimate the economic impacts of individual NASA centres (e.g. (NASA, 2018[44]; 2022[19])). In 2019, the agency commissioned a report to estimate the overall economic impact of NASA spending on the US economy (Highfill and MacDonald, 2022[46]; Voorhees Center, 2020[47]). Using information from BEA's supply-use tables, the study identified the direct, indirect, and induced effects of NASA spending on the US economy and state economies across all industries. In addition to NASA's direct budget expenditures, the study considered the new demand for goods and services resulting from NASA's expenditures, including products purchased along NASA's supply chain (indirect) and products purchased by the employees and business owners from NASA and its supply chain (induced). The study found that that NASA spending in the fiscal year 2019 had an overall impact of USD 64.3 billion in output and USD 35.3 billion in value added, which translates to 312 630 jobs and USD 23.7 billion in labour income. Most of the economic impact is attributable to indirect and induced effects. Only 5% of jobs and 12% of labour income can be directly attributed to NASA employees and their income.

Space economy input-output analyses typically focus on effects on output, employment, and government revenues. But they are often complex to realise, as reliable data may not be available for all three of these metrics due to the challenges associated with measuring the space economy outlined in Chapter 2. In the absence of detailed space economy statistics, the use of proxies is common and calculations tend to be based upon the results of ad-hoc surveys of space economy organisations or simple averages taken from broader categories of economic activity.

This makes it difficult to compare the findings of space economy IO analyses over time, with other areas of the economy and across countries. Furthermore, IO analysis should not be used uncritically. IO tables do not take into account supply-side constraints, some of which are crucial factors in the performance of the space economy such as the availability of skilled labour. This implies that, if the economy is operating at or near capacity, the realised effects are likely to be smaller than the results of an unsophisticated IO analysis would suggest. Finally, input output tables and multipliers should not be used out of context (i.e. in a different region or country), with different structural relationships between suppliers and a higher (or lower) dependence on traded products.

Extending input-output analysis to account for the environmental implications of space activities

Space economy studies have tended to focus on economic metrics such as output and employment. But input-output analysis is also a useful framework for understanding the use of natural resources in production and the discharge of pollutants into the environment as a result of industrial activity. An increasingly important extension to traditional IO-based economic impact assessment is the inclusion of alternative variables such as energy use. Space manufacturing, including product testing, is an energy-intensive activity. Several space agencies, including the German Aerospace Centre (DLR), ESA and NASA, increasingly provide environmental performance data for their facilities. Typically, water consumption, energy consumption and CO_2 emissions are measured among other variables (ESA, 2017[47]; DLR, 2018[48]). Figure 5.4 displays a visualisation of environmental monitoring conducted by the DLR of its facilities in Germany.

In general, environmentally extended IO tables account for both the natural inputs to an activity (whether they be material resources, renewable resources or other inputs such as soil nutrients) and the flow of residuals into the environment that results from that activity (such as air emissions, solid waste and wastewater). This physical information is then combined with the monetary information of the standard IO tables in order to provide an integrated summary of the environmental effects of a particular area of the economy. This method could be used to, for example, analyse the direct, indirect, and induced effects of space activities on generating greenhouse gas emissions. The results of which could be used to compare both the total positive economic effects (in terms of output, employment and government revenues) with the total negative environmental effects (in terms of greenhouse gas emissions, for example).

The specific effects of technology transferred from the space economy to the general economy

Space technology transfers to different sectors of the economy have evolved from being an accidental by-product of space research to a routine means of maximising the value of space research and development expenditure.

Many space technologies originate in the context of government-funded space programmes. Technological transfer and commercialisation (TTC) have therefore often been part of routine objectives since the 1960s and 70s. But in the last decade, the number and diversity of programmes and policies to transfer and commercialise space technologies has grown. Promoting different uses of space technologies is becoming an increasingly crucial task in space agencies' programme of work in many countries. Selected TTCs help broaden the benefits of public space R&D investments indirectly to the wider economy. This maximises the returns associated with the initial scientific and technology-intensive programmes, beyond simply fulfilling their primary mandates (e.g. achieving a successful space mission), although an economic framework of analysis is needed to assess their actual impacts.

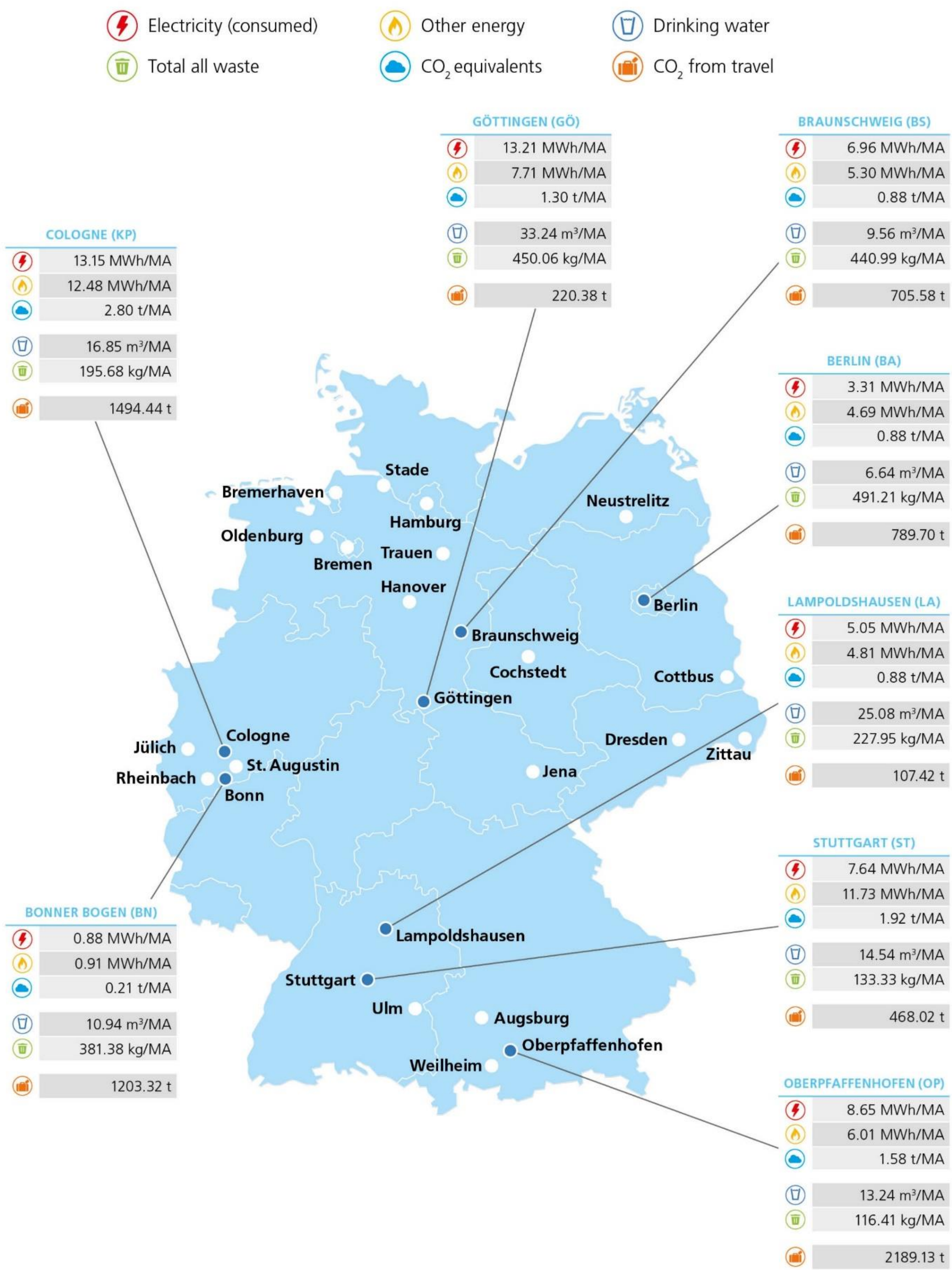
The OECD has examined space technology transfers and their commercialisation, focusing on transfers from publicly funded programmes to different sectors of the economy and comparing practices from Europe, North America and Asia (Olivari, Jolly and Undseth, 2021[50]). Space technological transfers and commercialisation are described in the analysis as the movement of know-how, skills, technical knowledge, procedures, methods, expertise or technologies from a public research organisation (e.g. space agency, space research centre) to another organisation operating in a different sector (e.g. a firm in the business enterprise sector).

Keeping track of the effects of space technology transfers is today mostly done through much broader evaluations of space activities and assessments of the commercialisation of government intellectual property in general.

In the United States, federal agencies tend to measure the benefits of their technology transfer programme via the number of patents and licensing income (Choudhry and Ponzio, 2020[50]). In order to complement this information, other ad-hoc studies are regularly conducted. For instance, an evaluation of Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programmes at NASA also provide useful insights (National Academies of Sciences, Engineering, and Medicine, 2016[51]). NASA and other US federal agencies with extramural R&D budgets exceeding USD 100 million are required to allocate 2.8% of their R&D budget to Small Business Innovation Research programmes. Another 0.3% for Small Business Technology Transfer programmes are required if their R&D budgets exceed USD 1 billion. A survey among recipients of SBIR and STTR funding from NASA found that participation in the programmes contributed to developing new markets, reputational effects, access to other federal agencies' programmes (outside the space programme), and connections to key stakeholders in core technical areas (including agencies, prime contractors, investors, suppliers, subcontractors, and universities) (National Academies of Sciences, Engineering, and Medicine, 2016[51]).

In Korea, on the occasion of the 30-year anniversary of the Korea Aerospace Research Institute (KARI) in 2019, the organisation conducted a large impact assessment of the institute's R&D activities over the last three decades. This included a systematic analysis of technological transfer activities, their outputs and outcomes covering all KARI aerospace programmes. The results show that since 2001, there have been a total of 326 technology transfers (an average of 18.1 transfers per year of which 81.3% were transfers of "technology" (as opposed to know-how)). The average improvement in annual sales of recipient firms attributable to the institute's R&D activities was valued at KRW 390 million (USD 330 000). Technology transfers were directly related to 20.3% of these additional sales (Park, 2020[52]). Furthermore, the utilisation by "internal" and "third party" actors of KARI facilities indicated significant growth in external usage over the years.

Figure 5.4. Environmental compliance of DLR institutes



Source: Grunewald, M. (2019[53]), “Sustainability indicators at DLR research institutes”.

Using government intellectual property commercialisation assessments to understand the effects of space technology transfers

When technology transfer occurs, intellectual property is one of the key elements to consider. A number of administrations and agencies have attempted to assess the benefits derived from the commercialisation of space-related patents through licensing.

Comstock and Lockney (2011[54]), for example, analyse the positive effects generated by the commercialisation of government intellectual property at NASA. The authors considered 187 transfers recorded in NASA's annual *Spinoff* publication between 2007 and 2011. They report benefits as revealed by recipient firms according to a consistent set of indicators, although only a minority of case studies report numeric data. The benefits range from new or additional jobs in the firms to revenues and environmental benefits (Table 5.3). Focusing on the economic effects of technology transfers from NASA's life sciences programme, Hertzfeld found substantial returns to the 15 firms that were surveyed based on their commercialisation of new products under NASA licenses (Hertzfeld, 2002[55]). All firms reported profitable product lines and provided evidence of positive effects extending to the users of their products.

Table 5.3. Selected benefits of NASA technological transfers

Indicators	Quantifiable benefits	Share of case studies with numeric data
New or additional jobs	1 665 new jobs collected from eight transfer stories (e.g. composite manufacturing).	4%
New or additional revenues	USD 532 million (mainly single year of sales) from nine transfer stories.	5%
Productivity/efficiency gains	NASA's research on winglet design (blended winglets) is estimated to have generated aircraft fuel cost savings of more than USD 4 billion over the 2006-10 period (see also environmental benefits).	2%
Lives saved	659 lives saved attributed to two tech transfers, including 450 lives saved attributed to Apollo-era lift raft technology used to manufacture rescue rafts.	1%
Lives improved	30 million lives improved attributed to 4 NASA tech transfers, notably unique nutritional supplements used in baby formula and new materials used in surgical implants.	2%
Environmental benefits	NASA's work on winglet design is estimated to have saved 21.5 million tons in CO_2 emissions over the 2006-10 period.	n.a.

Notes: n.a.= Not available. Data based on 187 tech transfer stories collected between 2006 and 2010.
Source: Comstock and Lockney (2011[54]), "A sustainable method for quantifying the benefits of NASA technology transfer", https://spinoff.nasa.gov/pdf/AIAA 2011 Quantifying Spinoff Benefits.pdf.

The European Space Agency support commercialisation of space technologies and services in general, including the commercialisation of its intellectual property via a network of 22 business incubation centres (BIC) in its member states. A 2020 assessment suggests the initiative has resulted in the creation of more than 700 firms since the launch of the first centres in 2003 and supports on average some 180 start-ups annually (ESA, 2020[56]). Other assessments suggest the performance of each BIC centre vary considerably depending on the metric under consideration. The ESA BIC in Harwell in the United Kingdom reported a firm survival rate of 92% since the creation of the incubation centre in 2011 (O'Hare, 2017[57]). The Bavarian ESA BIC, established in 2009, had in 2018 incubated a total of 130 start-ups, creating 1 800 jobs and generating EUR 150 million in annual turnover (ESA BIC Bavaria, 2021[58]).

Since its opening in 2016, ESA BIC Switzerland has supported 40 start-ups nationwide and invested a total of more than EUR 6 million non-dilutive funding from ESA. Start-ups in ESA BIC Switzerland have raised more than EUR 170 million in third party funding and created more than 300 domestic jobs. At least five of these start-ups have reported CHF 1 million (USD 1 million) in annual revenues and some have been supported by major organisations such as IBM. Perhaps the best-known alum of ESA BIC Switzerland is ClearSpace, which has received a contract of EUR 86 million from ESA to demonstrate the first space debris clearance mission (Startupticker ch, 2021[60]).

Challenges associated with understanding the effects of space technology transfers

The review of different types of positive effects generated by technological transfers shows that there is considerable anecdotal evidence of "success stories". There is also a growing amount of qualitative data, generally suggesting relevant impacts on recipient organisations, including academic organisations and firms.

However, the challenge remains to identify benefits that can be aggregated, analysed and compared. As shown in Table 5.3, only a tiny percentage of the NASA case studies reviewed by Comstock and Lockney provided quantitative data. Similarly, the type and amount of reporting from the European Space Agency Business Incubation Centres differs considerably from one centre to another.

The methodological challenges associated with identifying the different types of benefits from space technology transfers are the same as for many other government R&D programmes (Gaster, 2017[60]):

- **Lags:** There is sometimes a considerable time lag between the initial investment and the realised outcomes, sometimes several decades. Time lags are particularly relevant for space activities, exacerbated by long technological development lead times and small markets with limited commercial opportunities.
- **Limited institutional memory of firms:** Memories or records of past government projects may be limited, especially if they date back several years. This is perhaps particularly the case for small- and medium-sized enterprises, which are more susceptible to failure or acquisition than bigger firms.
- **Self-reported data:** Most outcomes mentioned in this section are self-reported, mostly via ad-hoc surveys and studies. Some organisations may make mistakes or inflate results, and there is no way to measure benefits over time unless there are repeat studies using the same indicators.
- **Problems of causality and quantification:** How much of an organisation's revenues can be attributed to a single project? Firms often need support from several projects and organisations to commercialise their products. Similarly, how much of a mature firm's revenues should be attributed to government funding (potentially received decades earlier)?

Some of these issues may be addressed by improved agency data collection and management practices, by creating incentives for self-reporting (e.g. associate it with future governmental funding), providing clear guidelines for the type of data to report and introducing follow-on surveys (National Academies of Sciences, Engineering, and Medicine, 2016[52]).

There are already ongoing efforts to harmonise knowledge transfer metrics across countries in Europe (Olivari, Jolly and Undseth, 2021[49]). Table 5.4 below shows the indicators used by the European Association of Knowledge Transfer professionals, for surveying technology transfer offices across Europe. This provides an exhaustive overview of typical indicators for mapping collaboration and intellectual property commercialisation. Some space agencies already follow this approach and are adopting some of these metrics.

The societal effects of information generated from satellite data

The deployment of large-scale government missions such as Global Navigation Satellite System (GNSS) constellations and GNSS-augmented missions in Europe, Asia and Oceania, as well as the European Copernicus programme, suggest that access to satellite data will continue to grow in the coming decades. As OECD Space Forum research suggests (OECD, 2019[61]; 2008[62]), many economic activities encompassing most sectors of the economy use a range of applications built upon satellite data in order to improve the information available to them in decision making. The benefits associated with the use of information generated from satellite data are broad and touch upon many areas of the economy.

Table 5.4. Selected general metrics used by technology transfer offices

Indicator	Description
Gross revenues from intellectual property rights (IPRs)	Overall revenues obtained by an agency through the concession of IPRs on its technologies (the aggregate include revenues from patent licenses as well as royalties and eventual income coming from the sale of equity in spin-off firms and/or start-ups linked to the transfer)
Gross revenues from patent licenses	Income earned by a firm for allowing its patented material to be used by another firm under the effects of a specific licence
Gross revenues from running royalties	Revenues tied to the turnover of a product sold (directly or indirectly) by a licensee
Number of active patent families	Number of patents families covered by the TTO's portfolio of active patents
Number of collaborative research agreements	Number of collaborative research agreements concluded by the TTO
Number of consultancy agreements	Number of consultancy agreements concluded by the TTO
Number of contract research agreements	Number of contract research agreements concluded by the TTO
Number of invention disclosures	An invention disclosure is a document that provides a complete description of something novel and non-obvious. It clarifies the characteristics of the novelty in such a manner that a third party could reproduce the invention described. The disclosure represents the first official recording of the invention and, if done properly, can establish an irrefutable date and scope of the invention
Number of licenses granted	Number of licenses granted and their nature (technology, software, research)
Number of patents granted	Number of patents the TTO has been granted
Number of priority patent applications	Number of new patent applications filed where the application is the first (or priority) application for a technology
Number of spin-off firms generated	Number of new spin-off firms generated, which operate using intellectual capital originated in the TTO. Spin-off firms count for their activity on a formal agreement with the TTO to use and exploit IPRs for the development of new products or services
Number of start-ups generated	Number of start-ups supported by the TTO. To note that start-ups do not count on IPR developed within the TTO to perform their activity and do not have any formal use agreement on specific technologies developed therein
Share of licensed patent families	Percentage of the total number patent families touched by the TTO's portfolio of active patents, which are currently licensed

Note: TTO=Technology transfer office
Source: Adapted from ASTP (2021[63]), "ASTP survey report on knowledge transfer activities in Europe", https://www.astp4kt.eu/about-us/kt-news/astp-survey-report-on-knowledge-transfer-activities-2020.html.

In the past five years, several initiatives, such as the GEOValue community, the NASA-funded VALUABLES Consortium and the Sentinel Benefits studies funded by the European Space Agency and the European Union, have contributed to producing more evidence in this area (GeoValue, 2021[65]; Valuables Consortium, 2021[66]; EARSC, 2021[67]). All these groups aim to collect and provide accessible case studies, community-accepted methodologies and peer-reviewed publications. In the United States, interagency discussions between key institutional operators and users of earth observation satellites, i.e. NASA, the United States Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA), are also contributing to exchanges of best practices. An international community of practitioners is forming, consisting of academia, national and international organisations, with the support of the Group on Earth Observations (GEO) and the OECD Space Forum, which hosted a GEOValue workshop in 2016 together with NASA and USGS.

The value chain approach to understanding the use of satellite data in society

The links between satellite data and better decisions can be studied using different approaches (Bernknopf et al., 2019[67]), including the concept of stylised value chains. The value chain begins with the transformation of unprocessed satellite data into information that is more readily usable, often through the development of data products and web applications (applications herein). Applications based on satellite data may be built by developers working in any sector operating in the downstream segment of the space economy as defined in Chapter 2. The rationale for devoting resources to the development of applications from satellite data may differ between sectors. Business enterprises seek to generate profit from the services their applications provide while government sector developers will often be motivated by the provision of public services. This section focuses on the societal effects of any satellite data application of the use in decision making and developed by any sector.

Illustrations of the value chain approach to understanding the societal effects of satellite data are commonplace. By way of example, a series of briefings on satellite data value chains are provided by a study conducted by the European Association of Remote Sensing Companies (EARSC et al., 2016[68]). Over 20 use cases outline the value chains of applications built upon data flowing from the European Union's Copernicus-Sentinel satellites. Examples of activities relying upon applications built upon satellite data include the management of farms, forests, floods and maritime navigation. The types of beneficiaries and the value generated at different stages of the value chain are assessed for each use case.

One such case study outlines the societal value of natural gas pipeline monitoring services in the Netherlands. The application developer supplements high-resolution commercial satellite data with Copernicus-Sentinel data in order to provide information services on the state of gas pipelines. The application developer is rewarded through the revenue it receives from selling its product to pipeline maintenance companies and to municipality governments. Through the use of the application, pipeline maintenance companies are better able to target their resources, conduct their activities more efficiently, and avoid costs in the process. And municipalities are better able to plan their expenditure on pipeline maintenance and ensure efforts are focused on priority areas that require the most attention. Ultimately, society benefits through the reduced risk of pipeline defects causing problems with the gas network, less disruption from unnecessary operations and maintenance, and a more efficient use of government revenues. Table 5.5 outlines the results of this case study including estimations of the monetary value of such positive effects across the different parts of the value chain.

Table 5.5. Pipeline infrastructure monitoring in the Netherlands

	Service provider	Primary users	Secondary beneficiaries	End use beneficiaries	Total
Actors	Private provider of InSAR maps	Infrastructure management companies	Municipalities	Wider public	n.a.
Benefits	Employment and revenues	Better maintenance and assets management	Better planning of maintenance activities	Household risk reduction and less disturbance from maintenance work	n.a.
Estimated annual benefits (2016)	EUR 0.5 million	EUR 11.1 million	EUR 3.3-6.6 million	n.a.	EUR 15.2-18.3 million

Note: n.a.= Not available.
Source: EARSC et al. (2016[68]), "Assessing the detailed economic benefits derived from Copernicus earth observation (EO) data with selected value chains: Pipeline infrastructure in the Netherlands", http://earsc.org/news/satellites-benefiting-citizens-the-case-of-pipeline-infrastructure-in-the-netherlands.

Using information theory to quantify the positive societal effects of satellite data

In general, the developers of applications directly benefit from the use of satellite data through the revenues generated by the provision of their services. The value of such transactions can be observed in the market prices paid by consumers – one way of calculating the total market value being to multiply the market price of a particular application by the quantity of application units sold. However, the remaining links in the value chain are characterised by non-market effects that are difficult to assign with a monetary value. While the value chain concept provides a framework for making explicit the links between satellite data and various forms of value, it does not provide a methodology for estimating monetary values for the non-market effects.

Consider, for example, weather forecasting, the producers of which are a major user group of satellite data. The value of satellite data in weather forecasts extends far beyond the revenues generated by the developers of weather applications as they market their products (Anderson et al., 2015[70]; Kull et al., 2021[71]). To focus on just one non-market effect, the information provided by weather forecasts enables decisions to be made that help society avoid costs that would have been incurred in the absence of the weather forecast. Examples of this scenario include early warning systems for flooding and heatwaves that enable preventative action to be taken and the costs associated with unmitigated disasters to be avoided (EUMETSAT, 2014[10]). There is no set of readily observable market transactions for the avoided costs of a natural disaster mitigated by decisions made due to the information provided by weather forecasts. So, the value of all the costs avoided in such an event must be estimated.

The non-market effects of the use of satellite data applications are often quantified using methods originating in an area of economics known as *information theory* (Macauley, 2005[72]; Pearlman et al., 2016[73]; Straub, Koontz and Loomis, 2019[74]). The theory proposes that data has little intrinsic value and only realises its full value once it is used as information (akin to the Copernicus-Sentinel satellite data informing decision making in pipeline maintenance in the Netherlands outlined above EARSC et al. (EARSC et al., 2016[68]). Furthermore, information developed from data is only likely to be required if some ambiguity in the potential outcomes of a decision exists. If there is no ambiguity, or uncertainty, then there would be no need for data to inform the decision-making process. The value of information (VOI) is therefore calculated as the difference between some measure of the outcomes associated with a decision based on the information under scrutiny and an estimate of the outcome that would have occurred had a decision been made without the information. It follows that information is higher in value when used to inform decisions that have important potential effects and are characterised by high uncertainty. In 2022, the European Space Agency commissioned a pilot study on the value of satellite observations (from the ESA Aeolus mission) to meteorological institutes, supported by the European Centre for Medium-Range Weather Forecasts (ECMWF).

Non-market effects of satellite-derived information

In practise, it is often useful to break down the value of information by the sector of the beneficiary. For example, the information generated from satellite data applications is often used by the business enterprise sector to improve decisions. The effects of better decision making in firms tends to be measured through gains in productivity (in whatever measure chosen) over counterfactual estimates of productivity in a scenario where satellite data does not exist or is of poorer quality. Often the magnitude of such effects reflects the degree to which a particular economic activity relies upon the information taken from satellite data applications – where the greater the uncertainty, the greater the reliance on the information – and the economic size of the particular area of the sector.

By way of example, applications based on data from GNSS have generated important positive productivity effects in road and maritime transportation industries by improving navigation and route planning. Productivity gains accrue to transportation companies as they are better able to plan routes in order to reduce their fuel consumption and optimise the time spent on delivery, thereby saving on expenses that would have occurred in absence of the satellite signals. But more efficient transport provision also has profound implications for every part of the economy that uses transportation services – which is to say all other economic activity involved in the manufacture and retailing of goods – through lower transport margins in the final prices of products. This suggests the value of this particular application extends far beyond that accruing to the developers of satellite signal-derived navigation aids and their immediate users. Table 5.6 provides estimations of the total value of information generated from the Global Positioning System (GPS) in business enterprises across a range of economic activities in the United States taken from a 2019 study by the Research Triangle Institute.

Table 5.6. Estimated benefits to business enterprises derived from the use of the Global Positioning System

Sector	Contribution of GPS (precision, navigation and timing)	Estimated cumulative monetary benefits, United States (1984-2017)
Telecommunications	• Improved reliability and bandwidth utilisation for wireless networks	USD 686 billion[1]
Telematics (fleet management, logistics)	• Improved vehicle dispatch • Navigation aids • Reduced use of fuel • Reduced labour costs	USD 325.2 billion
Surveying	• Increased accuracy of services • Reduced labour costs	USD 48.1 billion
Oil and gas	• Increased oil and gas yield • Increased accuracy • Enables deep water operations • Reduced labour costs	USD 45.9 billion
Electricity	• Improved system reliability and efficiency	USD 15.7 billion
Mining	• More efficient allocation and dispatch of equipment • Increased ore yield • Increased accuracy of site surveying and digging • Reduced labour costs	USD 12.3 billion
Agriculture	• Increased crop yield • Reduced use of seeds, fertilizer, water • Reduced labour costs	USD 5.8 billion

1. Valuated using willingness-to-pay.
Source: Based on O'Connor et al. (2019[74]), "Economic benefits of the Global Positioning System (GPS): Final report", https://www.rti.org/sites/default/files/gps_finalreport.pdf.

The business enterprise sector satellite data value chain is complex and contains many aspects that are difficult to quantify. But examples of the use of satellite data by the government sector also abound (ACIL Allen, 2015[22]; 2013[23]). The effects of improved public policy making as a result of the information developed from satellite data can be even more difficult to value monetarily than those apparent in the business enterprise sector due to their public good nature and sheer scale. Consider, for example, the role of government organisations in monitoring the environment and implementing policies to safeguard it – activities that generate many non-market effects and are regularly explored in the evaluation literature.

Satellites may carry atmospheric sensors capable of collecting data used to measure the level of air pollutants (CEOS, 2015[76]; Sullivan and Krupnick, 2018[77]). Once processed, this data may be developed into applications used to monitor air quality at local scales. Such information allows regulators to track pollution levels and provides evidence on whether or not they are below the level that regulations stipulate they must be. In some cases, sensors are able to monitor areas of just a few square kilometres which is smaller than most municipalities. The availability of the satellite data displaces some of the costs of constructing and maintaining an elaborate ground-based sensor network. In some cases, satellite-based measurements may even act as a substitute to in-situ sensors.

Perhaps the most profound effects of the decisions made using information generated from atmospheric sensors concern public health and safety. A 2018 Resources for the Future study suggests that the information provided by satellite-derived air pollution monitoring systems in the United States saves roughly 2 700 lives annually over and above an alternative scenario where monitoring does not occur (Sullivan and Krupnick, 2018[77]). The statistical value of the lives saved amounts to over USD 24 billion each year. In Europe, the value of avoided hospitalisations as a result of poor air quality warnings based on satellite data and sent to vulnerable people has been projected to accumulate to between EUR 8.3 million and EUR 21 million by 2035 (PwC, 2017[78]).

Strengthening space economy impact assessments

The sections above outline the current state of understanding with regards to the economic and social effects of the space economy across four major areas. Efforts in multiple countries and by international organisations mean the number and quality of publicly available assessments of the overall impact of space activities are increasing. However, space economy impact assessment remains a challenging field. Overall, the results of many impact assessments conducted in the sector tend not to be robust over time, comparable with other sectors or across countries.

The following analysis considers the field of space economy impact assessment as a whole. The major challenges associated with it are highlighted and various recommendations for changes are provided that may assist space economy analysts with achieving robust evaluations.

Key take-aways: Addressing the challenges associated with space economy impact assessment

The information required to conduct space economy impact assessments is generally not readily available and is often gathered on a case-by-case basis: This includes information developed from official economic statistics (as discussed in previous chapters in this *Handbook*), information on how space activities might relate to market outcomes, and information concerning how the use of particular space economy goods and services might affect society more broadly. Without regular and standardised reporting of the type of data required to create such information, space economy analysts must collect it themselves ex post and/or rely upon proxy measures. Furthermore, the effects of space activities are likely to vary in the time it takes for them to be realised. This means that information collected in the present may poorly represent the full value of space activities through time.

Information is particularly scarce with regards to the non-market effects of space activities: The most common approaches to evaluating the non-market effects outlined in this chapter include the estimation of replacement/substitution costs (e.g. aerial surveys), production factor costs (e.g. reduced labour costs) and cost avoidances. Other approaches, such as contingent valuation (willingness-to-pay) have also been used. Estimating this type of information and developing the adequate level of data can be a long, complex and costly exercise. For example, a 2018 study estimating the value of GPS to the United States lasted three years and combined insights from almost 200 experts (O'Connor et al., 2019[75]).

As a result, space economy impact assessments, tend to be highly subjective and lack coherence with other areas: Results are often heavily reliant on case studies and expert opinion which can make it difficult to test them for validity and compare with other areas. Robust counterfactuals are not always developed, which increases the risk that the effects under assessment are poorly estimated. For example, when estimating the additional revenues from a new satellite data derived service, only the revenues that can be attributed to satellite data in isolation of all other data sources should be counted.

Countries may consider the following recommendations

Develop overall results-oriented evaluation frameworks supported by adequate resources: Countries are encouraged to develop frameworks that align policy objectives with indicator needs. In this way, there is more clarity about *what* to measure and a better guarantee that the ensuing assessment informs policy decisions. However, expanded data collection requires substantial resources. In order to leverage these efforts, the use of internationally recognised definitions and standard indicators makes it possible to compare findings and outcomes across agencies, sectors and countries. Although there is a push for the increasing quantification of indicators, it is also important to recognise that not all aspects can be treated in a quantitative way. Qualitative impacts of space activities and programmes should be included in the analysis and accounted for in the most objective and systematic manner possible.

Reinforce efforts in the collection of space economy statistics to improve impact assessments: Many countries have made great progress in economic measurement, notably by estimating contributions of the space economy to national GDP or supporting the collection of economic data from industry. However, reporting on the effects of participation in space programmes can be challenging for both smaller and larger organisations due to the difficulties of estimating counterfactuals. In order to decrease reporting burdens placed on participating organisations, few space agencies request data from their contractors in the first place and some organisations may have little obligation or incentives to provide information. Annual surveys of participants in space programmes from all sectors will systematically capture longer-term effects.

Document and share methodologies widely: Ensuring that methodological choices are transparent and well documented should enable reproducibility of results, while improvements in evaluation design could make findings more persuasive to decision makers. The OECD Space Forum will continue to work with ministries, space agencies, other administrations, academia, industry associations, business enterprises, and other international organisations, to better measure the impacts of space investments on society and the economy.

Annex 5.A. Space economy evaluation studies

The number of evaluations and impact assessments on space activities keep growing across OECD countries and beyond, as governmental agencies try to track the socio-economic effects of space programmes. A few of these studies are referenced below for information purposes. The proposed list is far from exhaustive.

Annex Table 5.A.1. Selected evaluations and impact assessments of space activities

Country/Region	Organisation	Selected publicly available reports conducted internally or commissioned
Australia	Department of Industry, Innovation, Climate change, Research and Tertiary Education	Augmented global navigation satellite systems (ACIL Allen, 2013[23]) Earth and marine observations ((Nous Group, 2019[78])
	Geoscience Australia/FrontierSI	Geospatial information: (ACIL Tasman, 2008[79]) Earth observation: (ACIL Tasman, 2010[80]; ACIL Allen, 2015[22]; Deloitte Access Economics, 2021[81])
Canada	Canadian Space Agency	Space sector: (Euroconsult, 2015[82]) and State of the Canadian Space Sector reports Canada-ESA Cooperation agreement: Canadian Space Agency (2009)
Denmark	Danish Agency for Science, Technology and Innovation	Space sector: (London Economics and Rambøll Management Consulting, 2016[83]) ESA membership: (Ramboll Management Consulting, 2008[29])
Europe	European Space Agency	ESA programmes: (Bramshill Consultancy Ltd, 1999[84]; BETA, 1991[27]; Euroconsult, 1985[85]) Ground systems engineering and operations: (PwC, 2019[86]) Science: (PwC, 2019[7]), Earth observation: (PwC, 2006[88]; 2019[21]; EARSC et al., 2018[89]; 2016[90]; 2016[91]; 2015[92]) Satellite communications: (Euroconsult, 2019[24]; Euroconsult et al., 2019[93]; Eftec, 2013[20]) Launchers (PwC, 2014[17]; Bramshill Consultancy Ltd, 2001[93]) International Space Station: (PwC, 2016[94]) Space situational awareness: (PwC, 2016[95])
	European Space Agency facilities	ESTEC, The Netherlands: (General Technology Systems, 1991[96]) ESOC, Germany: (Accenture, 2008[97])
	Eumetsat	EPS/Metop 2: (EUMETSAT, 2014[10])
	European Union	EU space activities: (Booz & Company, 2014[98]) Earth observation/Copernicus: (European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, 2016[99]; 2019[100]; 2017[77]; Booz & Company, 2011[8]) GNSS/Galileo-EGNOS: (PwC, 2001[103])
France	INSEE, French Guiana	Kourou Space Centre: (INSEE, 2017[102]) and similar report in 2009
Italy	Italian Space Agency (ASI) and Università di Milano	Cost-benefit analysis highlighting the role of public policies in the space sector (Università di Milano and Agenzia Spaziale Italiana, 2021[12])
India	Indian Space Research Organisation (ISRO)	Cost-benefit analysis of the Indian space programme (Sridhara Murthi, Sankar and Madhusudhan, 2007[11])
Netherlands	Ministry of Economic Affairs and Climate Policy	Space programmes: (Dialogic and Decisio, 2016[42]; Dialogic, 2020[103]) Space research: (Dialogic, 2021[104])

Country/Region	Organisation	Selected publicly available reports conducted internally or commissioned
Norway	Norwegian Space Agency	Space programmes: (PwC, 2012[105]) ESA membership (Norwegian Space Agency, 2018[28]) and similar reports ESA voluntary programmes and national programme: (Menon Economics, 2016[108]) ESA science programme: (Høegh Berdal, 2018[25]) Copernicus/Galileo/EGNOS membership: Oslo Economics (2019[107])
Portugal	Foundation for Science and Technology, FCT	ESA membership: (Clama Consulting, 2011[30])
Sweden	Swedish Space Agency	National earth observation programme: (Technopolis, 2013[108])
Switzerland	Swiss Space Office	Institutional R&D funding instruments: (Barjak, Bill and Samuel, 2015[26])
United Kingdom	UK Space Agency	Space sector: (London Economics, 2015[18]) ESA ARTES programme: (Technopolis, 2019[31]) National programmes: (Technopolis, 2018[109]) Spillovers: (London Economics, 2018[32])
	Innovate UK	Earth observation: (London Economics, 2018[110])
United States	Bureau of Economic Analysis	US space economy: (Highfill, Jouard and Franks, 2020[111])
	NASA	NASA programmes (Tauri Group, 2013[112]; Highfill and MacDonald, 2022[45]; Voorhees Center, 2020[46]) Earth observation: (Macauley, 2005[71]), (Bernknopf et al., 2018[113]), (Bernkopf et al., 2019[114]), (Sullivan and Krupnick, 2018[76]) Life sciences R&D: (Hertzfeld, 1998[115])
	NASA/NOAA	Space weather: (Teisberg, Weiher and Bardach, 2000[116])
	NASA facilities	Kennedy Space Center, Florida: (Florida Tech, 2022[19]) and previous years Marshall Space Center, Alabama: (NASA, 2017[117]; 2018[44]) and previous years
	Federal Aviation Authority	Commercial space transportation: (FAA, 2010[118]) and similar reports in 2001, 2003, 2006
	Office of Science and Technology Policy/USGS	Earth observation/Landsat: (Loomis et al., 2015[119]; Miller et al., 2013[120]; Straub, Koontz and Loomis, 2019[73]; NGAC, 2014[121])
	National Institute of Standards and Technology	GPS: (O'Connor et al., 2019[74])
International	International Space Exploration Coordination Group (ISECG)	Space exploration: (ISECG, 2013[122])
	International Space Station Program Science Forum (ASI, CSA, ESA, JAXA, ROSCOSMOS)	International Space Station: (ISS Program Science Forum, 2019[123]) and previous editions in 2015 and 2012

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Annex A. Glossary

Applied R&D: Original investigation undertaken in order to acquire new knowledge. It is directed primarily towards a specific, practical aim or objective.

Application for a patent: To obtain a patent, an application must be filed with the authorised body (patent office) with all the necessary documents and fees. The patent office will conduct an examination to decide whether to grant or reject the application.

Baseline: The baseline is the set of market projections used as a benchmark for the analysis of the impact of different economic and policy scenarios.

Basic research: Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.

Bibliometrics: Study of the quantitative data of the publication patterns of individual articles, journals, and books in order to analyse trends and make comparisons within a body of literature.

Business enterprise expenditure on R&D (BERD): Represents the component of GERD incurred by units belonging to the Business enterprise sector. It is the measure of intramural R&D expenditures within the Business enterprise sector during a specific reference period.

Counterfactual: In impact evaluation, the counterfactual refers to what would have happened to potential beneficiaries in the absence of an intervention. Impacts can thus be estimated as the difference between potential outcomes under observed and unobserved counterfactual treatments. An example is estimating the causal impacts of a policy "treatment" to support innovation activities. The researcher cannot directly observe the counterfactuals: For supported firms, what would have been their performance if they had not been supported, and similarly with non-supported firms.

Cost-benefit analysis: The quantification of the total social costs and benefits of a policy or a project, usually in monetary terms. The costs and benefits concerned include not only direct pecuniary costs and benefits, but also externalities, meaning external effects not traded in markets. These include external costs, for example pollution, noise, and disturbance to wildlife, and external benefits such as reductions in travelling time or traffic accidents.

Costs avoidances: They are actual or imputed costs for preventing environmental deterioration by alternative production and consumption processes, or by the reduction of or abstention from economic activities. Costs can also be averted in times of natural and technological disasters by mitigation processes and systems, to which satellites increasingly contribute.

Damage cost: Damage cost is the cost incurred by repercussions (effects) of direct environmental impacts (for example, from the emission of pollutants) such as the degradation of land or human-made structures and health effects. In environmental accounting, it is part of the costs borne by economic agents.

Evaluation: The systematic and objective assessment of an on-going or completed project, programme or policy, its design, implementation and results. The aim is to determine the relevance and fulfilment of objectives, efficiency, effectiveness, impact and sustainability.

Externalities: Externalities refers to situations when the effect of production or consumption of goods and services imposes costs or benefits on others that are not reflected in the prices charged for the goods and services being provided.

Full-time equivalent (FTE): The ratio of working hours during a specific reference period (usually a calendar year) divided by the total number of hours conventionally worked in the same period by an individual or by a group.

Gross domestic product (GDP): Gross domestic product is an aggregate measure of production equal to the sum of the gross values added of all resident institutional units engaged in production (plus any taxes, and minus any subsidies, on products not included in the value of their outputs). The sum of the final uses of goods and services (all uses except intermediate consumption) measured in purchasers' prices, minus the value of imports of goods and services, or the sum of primary incomes distributed by resident producer units.

Government budget allocations for R&D (GBARD): Government budget allocations for R&D encompasses all spending allocations met from sources of government revenue foreseen within the budget such as taxation. Spending allocations by extra-budgetary government entities are only within the scope to the extent that their funds are allocated through the budgetary process. Likewise, R&D financing by public corporations is outside the scope of GBARD statistics as it is based on funds raised within the market and outside the budgetary process. Only in the exceptional case of budgetary provisions for R&D to be carried out or distributed from public corporations should this be counted as part of GBARD.

Gross domestic expenditure on R&D (GERD): Total intramural expenditure on R&D performed in the national territory during a specific reference period.

Gross domestic product (GDP) deflator: Volume of gross domestic product (GDP) calculated by recalculating the values of the various components of GDP at the constant prices of the previous year or of some fixed base year, frequently referred to as "GDP at constant prices", divided by GDP at current prices.

Headcount: The headcount of personnel is defined as the total number of individuals at the level of a statistical unit or at an aggregate level, during a specific reference period (usually a calendar year).

Innovation: An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process).

Innovation activities: Institutional units can undertake a series of actions with the intention to develop innovations. This can require dedicated resources and engagement in specific activities, including policies, processes and procedures.

International Patent Classification (IPC): The International Patent Classification, which is commonly referred to as the IPC, is based on an international multilateral treaty administered by WIPO. The IPC is an internationally recognised patent classification system, which provides a common classification for patents according to technology groups. IPC is periodically revised in order to improve the system and to take account of technical development. The current (eighth) edition of the IPC entered into force on 1 January 2006.

Intellectual property rights (IPR): IPR allows people to assert ownership rights on the outcomes of their creativity and innovative activity in the same way that they can own physical property. The four main types of intellectual property rights are patents, trademarks, designs and copyrights.

Input-output table: An input-output table is a means of presenting a detailed analysis of the process of production and the use of goods and services (products) and the income generated in that production; they can be either in the form of (a) supply and use tables or (b) symmetric input-output tables.

Intermediate inputs: Goods and services, other than fixed assets, used as inputs into the production process of an establishment that are produced elsewhere in the economy or are imported. They may be either transformed or used up by the production process. Land, labour, and capital are primary inputs and are not included among intermediate inputs. Also called: “intermediate products”.

Market failure: General term describing situations in which market outcomes are not Pareto efficient. Market failures provide a rationale for government intervention. Context: There are a number of sources of market failure. For the purposes of competition policy, the most relevant of these is the existence of market power, or the absence of perfect competition. However, there are other types of market failures that may justify regulation or public ownership. When individuals or firms impose costs or benefits on others for which the market assigns no price, then an externality exists. Negative externalities arise when an individual or firm does not bear the costs of the harm it imposes (pollution, for example). Positive externalities arise when an individual or firm provides benefits for which it is not compensated. Finally, there are cases in which goods or services are not supplied by markets (or are supplied in insufficient quantities). This may arise because of the nature of the product, such as goods which have zero or low marginal costs and which it is difficult to exclude people from using (called public goods; for example, a lighthouse or national defence). It may also arise because of the nature of some markets, where risk is present (called incomplete markets; for example, certain types of medical insurance).

Multinational enterprise (MNE): Refers to a parent company resident in the country and its majority-owned affiliates located abroad, which are labelled controlled affiliates abroad (CAA). MNEs are also referred to as global enterprise groups.

Multiplier: A formula relating an initial change in spending to the total change in activity that will result. The multiplier was central to the argument for demand management in Keynesian economics. It is based on the argument that an increase in government spending becomes income for consumers. Some of this income is saved but some is spent. The cycle is then repeated, resulting in the initial increase in expenditure being multiplied.

North American Industry Classification System (NAICS): An industry classification system used by statistical agencies to facilitate the collection, tabulation, presentation, and analysis of data relating to establishments. NAICS is erected on a production-oriented conceptual framework that groups establishments into industries according to similarity in the process used to produce goods or services. Under NAICS, an establishment is classified to one industry based on its primary activity. NAICS was developed jointly by Canada, Mexico, and the United States to provide comparability in economic statistics. It replaced the Standard Industrial Classification (SIC) system in 1997.

North American Product Classification System (NAPCS): A multi-phase effort by Canada, Mexico, and the United States to develop a comprehensive list of products, product definitions, and product codes that will be organized into an integrated demand-based classification framework that classifies both goods and services according to how they are principally used. It is intended that NAPCS will be used throughout the statistical community to coordinate the collection, tabulation, and analysis of data on the value of products produced by both goods- and services-producing industries and on the prices charged for those products. The focus in the initial phases of NAPCS will be directed at identifying and defining the products of services-producing industries. NAPCS will be a complementary but independent classification system to NAICS.

Open innovation: Open innovation denotes the flow of innovation-relevant knowledge across the boundaries of individual organisations. This notion of “openness” does not necessarily imply that knowledge is free of charge or exempt from use restrictions.

Output: Output consists of those goods or services that are produced within an establishment that become available for use outside that establishment, plus any goods and services produced for own final use. In performance assessment in government, outputs are defined as the goods or services produced by government agencies (e.g. teaching hours delivered, welfare benefits assessed and paid).

Outcome: An outcome is defined as the impact on social, economic, or other indicators arising from the delivery of outputs (e.g., student learning, social equity).

Product: A product is a good or service (including knowledge-capturing products as well as combinations of goods and services) that results from a process of production.

Public sector: The public sector includes all institutions controlled by government, including public business enterprises. The latter should not be confused with publicly listed (and traded) corporations. The public sector is a broader concept than the General government sector.

Research and experimental development (R&D): Comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge.

Revenues: Revenues (or total revenue) refer to the value of output sold, that is the number of units times the price per unit. Average revenue is revenue per unit, which is total revenue divided by the amount of output sold. Average revenue is therefore equal to price per unit. The term "revenue" is often used interchangeably with "sales" and "turnover".

R&D grants: R&D grants, often also described as R&D subsidies, are funding flows from one statistical unit to another statistical unit to perform R&D that does not require any good or service in return and where the funder is not entitled to any significant rights on the outcome of the R&D it has funded.

R&D procurement: R&D procurements are funding flows from one statistical unit to another statistical unit in return for the performance of R&D and the delivery of relevant R&D outcomes.

Sales: Sales measures gross operating revenues minus rebates, discounts, and returns. Sales should be measured exclusive of consumption and sales taxes on consumers, as well as value added taxes. See also Turnover and Revenues.

Satellite account: Satellite accounts provide a framework linked to the central accounts and which enables attention to be focused on a certain field or aspect of economic and social life in the context of national accounts. Common examples are satellite accounts for the environment, or tourism, or unpaid household work.

Small and medium-sized enterprises (SMEs): Small and medium-sized enterprises (SMEs) are non-subsidiary, independent firms which employ less than a given number of employees. This number varies across countries. The most frequent upper limit designating an SME is 250 employees, as in the European Union. However, some countries set the limit at 200 employees, while the United States considers SMEs to include firms with fewer than 500 employees. Small firms are generally those with fewer than 50 employees, while micro-enterprises have at most 10, or in some cases 5, workers.

Socio-economic objective (SEO): Classification used to distribute GBARD. The criteria for classification should be the purpose of the R&D programme or project, i.e. its primary objective. The allocation of R&D budgets to socio-economic objectives should be at the level that most accurately reflects the funder's objective(s). The recommended distribution list is based on the European Union classification adopted by Eurostat for the Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets (NA BS) at the one-digit level.

System of National Accounts (SNA): The international standard for the compilation of national accounts statistics. It consists of a coherent, consistent and integrated set of macroeconomic accounts, balance sheets and tables based on a set of internationally agreed concepts, definitions, classifications and accounting rules. The System of National Accounts 2008 (SNA) has been prepared under the joint responsibility of the United Nations, the International Monetary Fund, the Commission of the European Communities, the OECD and the World Bank.

Turnover: The totals invoiced by the observation unit during the reference period, and this corresponds to the market sales of goods or services supplied to third parties. Reductions in prices, rebates and discounts as well as the value of returned packaging must be deducted. Price reductions, rebates and bonuses conceded later to clients (e.g. at the end of the year) are not taken into account. See also Sales and Revenues.

Value added: The total sales of a firm minus purchases of inputs from other firms. What is left is available for the wages of its employees and the profits of its owners. National income is the sum of value added in all enterprises in the economy.

OECD Handbook on Measuring the Space Economy, 2nd Edition

Much has changed in the space economy over the past decade, with an ever-growing number of countries and business enterprises involved in space activities. Despite progress made in the quality and availability of data, the international comparability of space economy statistics remains limited. A decade after its first publication, it is therefore time to provide an up-to-date revision of the *OECD Handbook on Measuring the Space Economy* to reflect the changing landscape of space activities, space technologies and subsequent evolving user needs. This new edition aims to encourage and facilitate data collection among both incumbents and new actors involved in space activities, respond to the needs of the public agencies that still fund the bulk of space programmes, and support industry and private decision-takers who will also benefit from improved statistics on the space economy.

PRINT ISBN 978-92-64-39938-9
PDF ISBN 978-92-64-67115-7

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