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]).

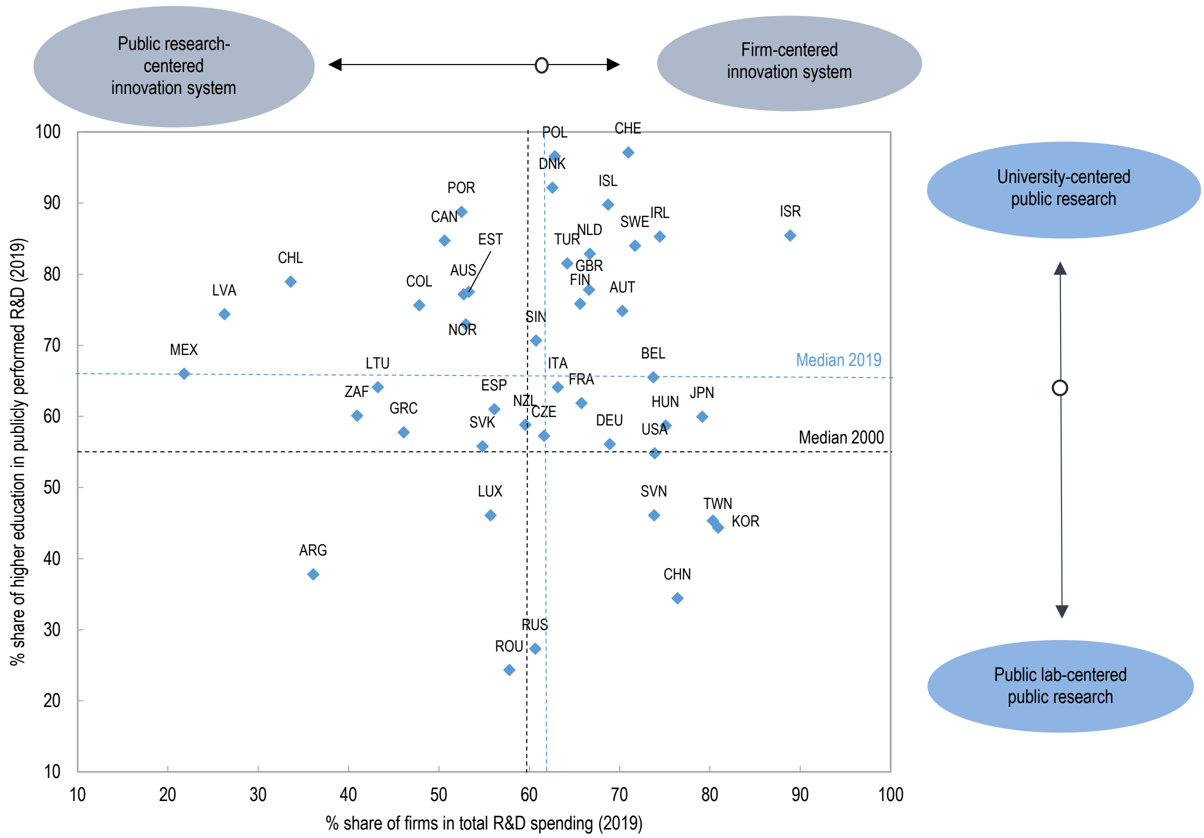
Governments therefore need to keep track of how, where and by whom space activities are being conducted in order to tailor public policy accordingly. In order to assist governments in their efforts to understand space activities, this chapter aims to provide a comprehensive overview of the actors, definitions 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

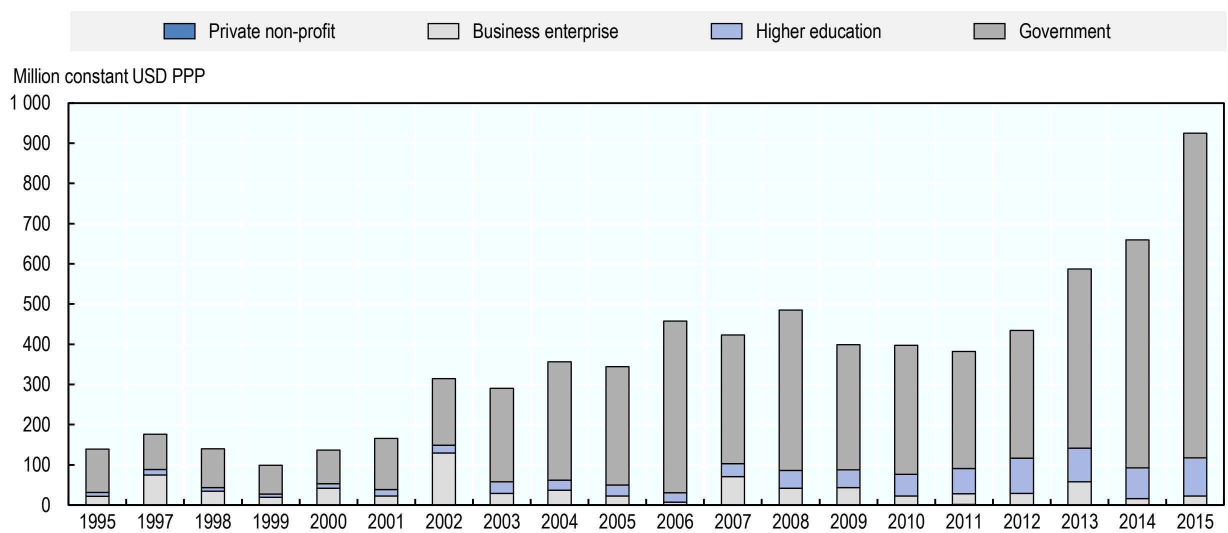
Government research institutes and laboratories have traditionally carried out the bulk of public space-related R&D in OECD countries. Some research institutes are entirely dedicated to space activities. The most prominent example is perhaps the Jet Propulsion Laboratory (JPL) in the United States, which 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).

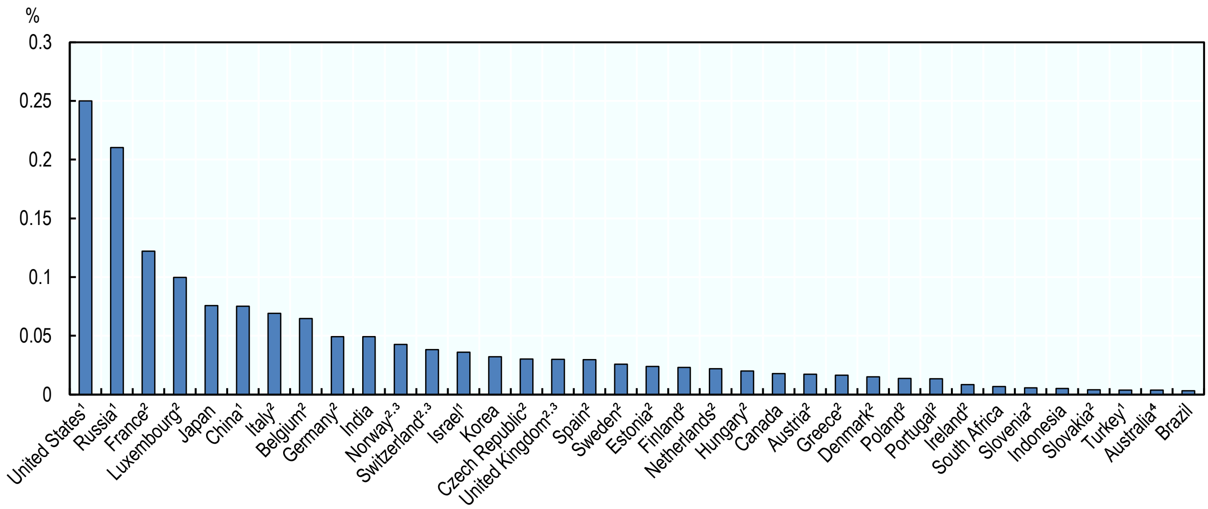
Since 2015, Korea has taken steps to move away from this government-led model, seeking to transfer initiative and responsibility to the private sector through formal partnerships and by procuring services (Undseth, Jolly and Olivari, 2021[1]).

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.

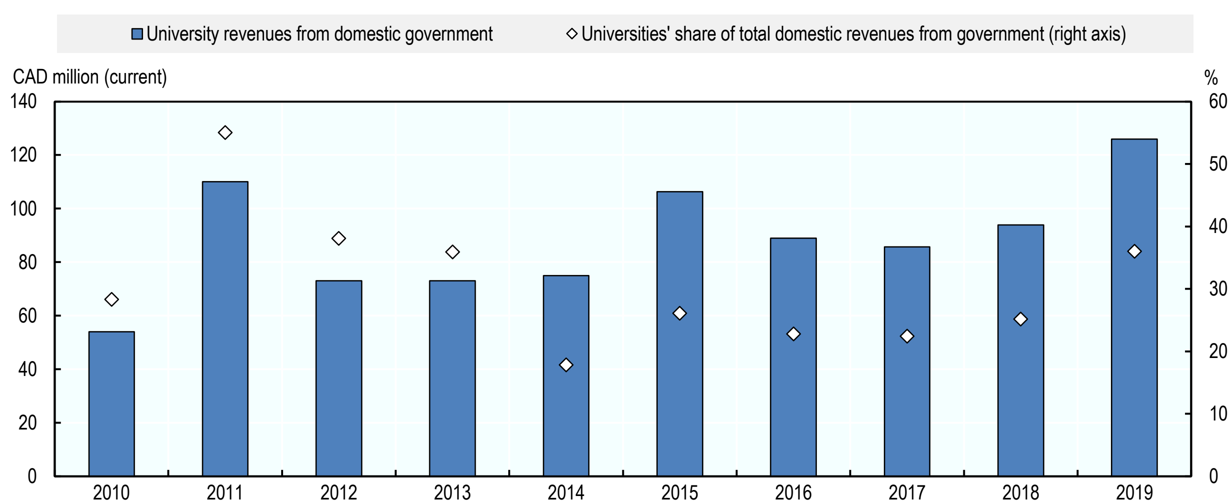
However, other data sources exist that can help outline and understand higher education organisations according to their purpose, including:

- 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



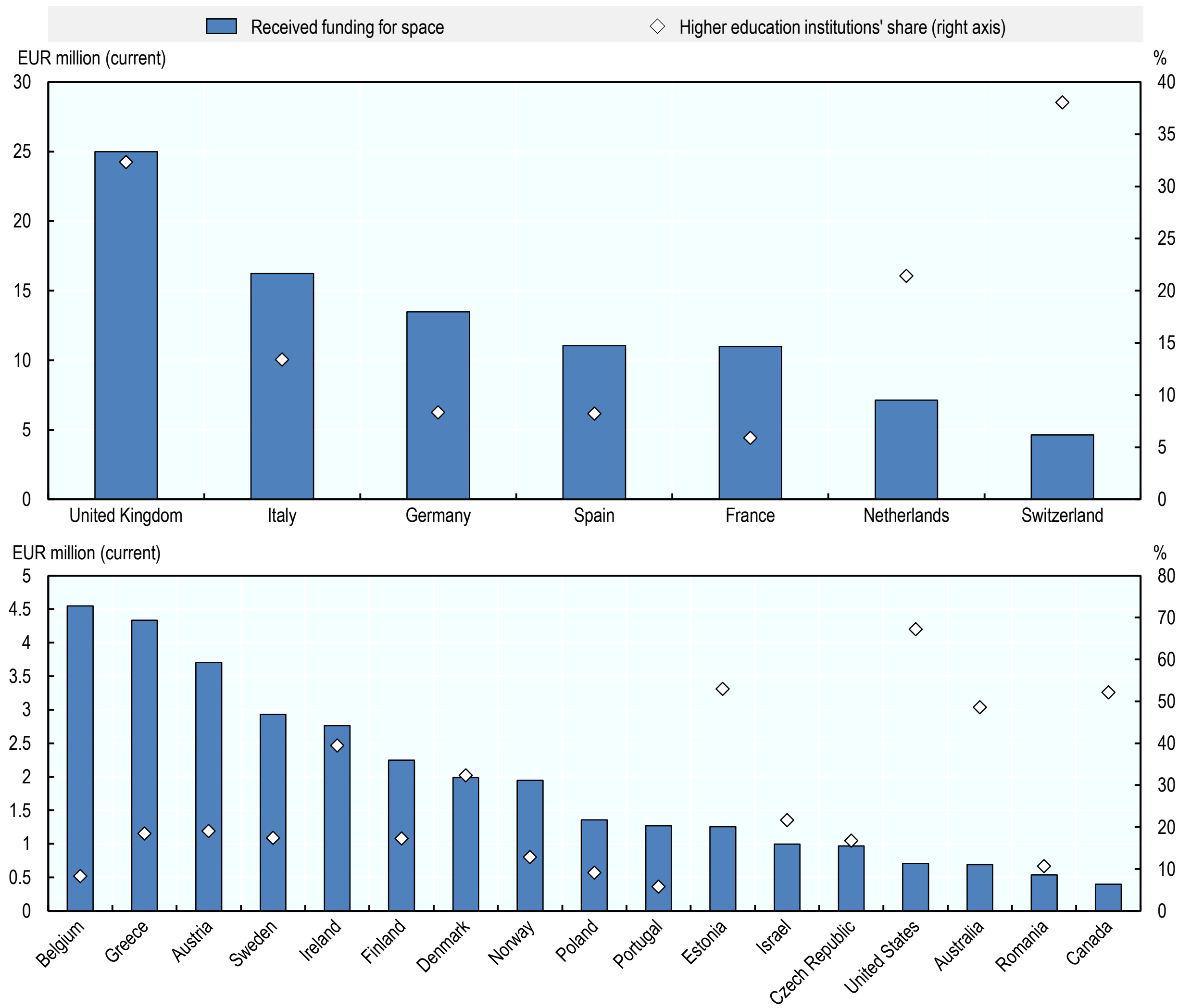
Source: Canadian Space Agency (2022[9]), "The state of the Canadian space sector 2019" and equivalent reports for the years 2010-20, https://www.asc-csa.gc.ca/eng/publications/2020-state-canadian-space-sector-facts-figures-2019.asp#results.

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



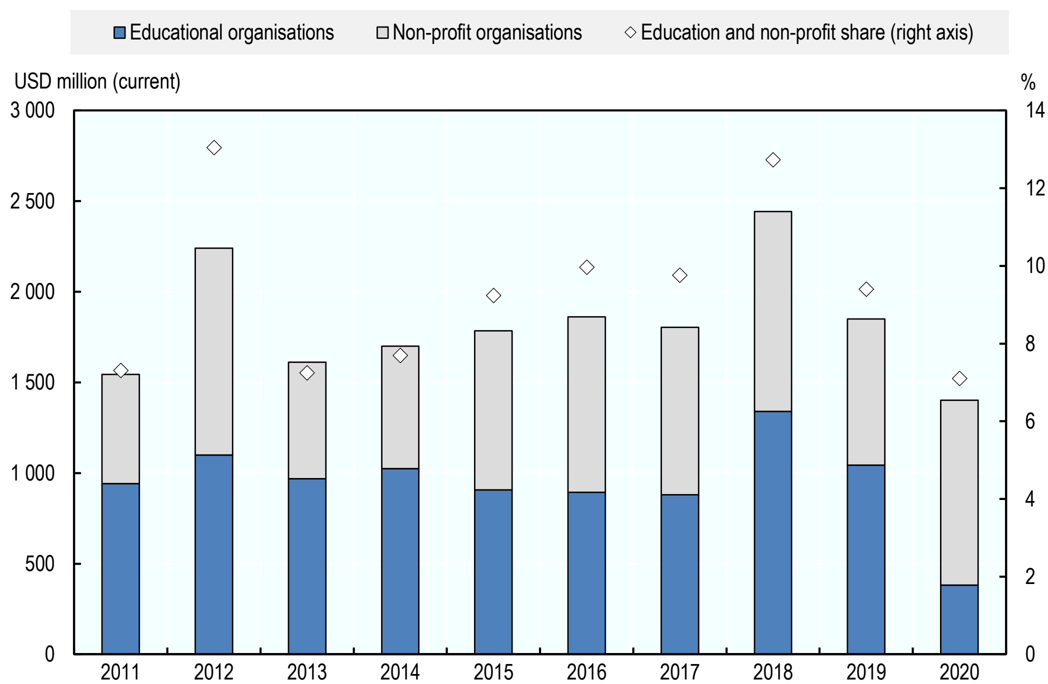
Notes: Horizon 2020 institution categories do not correspond to the institution categories in the *Frascati Manual*. In the *Frascati Manual*, research centres are mainly categorised under "Higher Education" or "Government sector". The figure was split in two to allow a maximum of countries to appear 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.

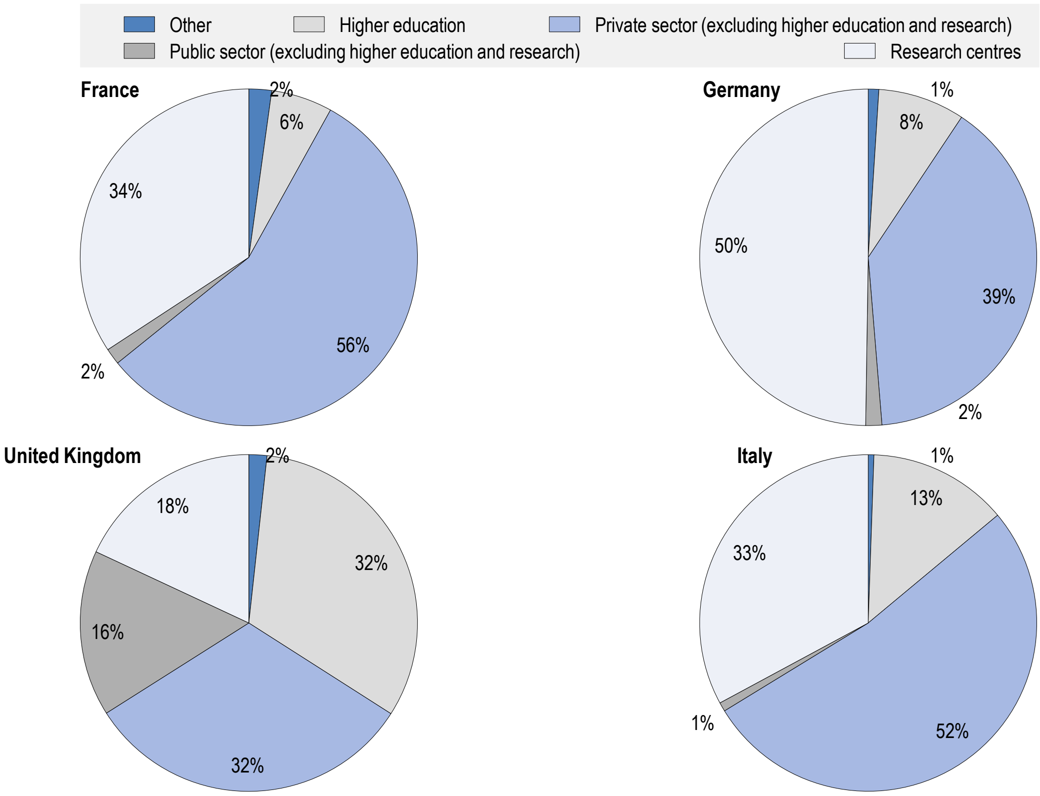
The sector comprises both private and public enterprises. If public-private partnerships have the status as institutional units, the classification depends on the institution with the greatest interest in the partnership. The activities of enterprises can be identified, outlined and understood using 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]).

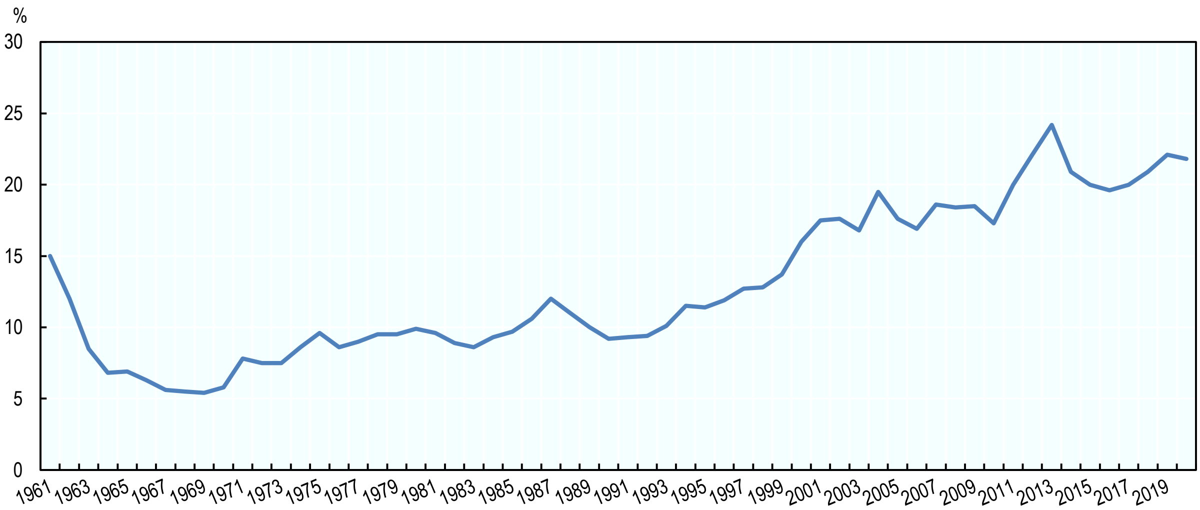
In Europe, associations representing space manufacturing industries (Eurospace) and remote sensing companies (European Association of Remote Sensing Companies – EARSC) track SMEs among their respective members. According to Eurospace, some 8-16% of space manufacturing employment was to be found in SMEs 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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From:
OECD Handbook on Measuring the Space Economy, 2nd Edition

Access the complete publication at:
https://doi.org/10.1787/8bfef437-en

Please cite this chapter as:

OECD (2022), “Monitoring the evolving cast of space actors”, in *OECD Handbook on Measuring the Space Economy, 2nd Edition*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/9e10dc7b-en