STI Policy Note
October 2016

Space and Innovation

How do Space Activities Relate to the Global Economy?

In our interconnected world, science and technology are a major source of innovation, productivity and economic growth. The space sector has been playing its part, having been for decades a driver of scientific exploration and knowledge, a sector with cutting-edge technologies, and a source of innovation that has increasingly diffused to other economic sectors. Many essential activities would be almost unthinkable today without satellite technology, like weather forecasting, or global communications and broadcasting.

This OECD report highlights innovation dynamics that are transforming the space sector and provides recommendations for tracking and sustaining space innovation.

The quick read

After decades of innovation, satellites now play a discrete but pivotal role in the efficient functioning of modern societies and their economic development.

The publication provides the findings from an OECD Space Forum project on the state of innovation in the space sector, with a view to examine how space innovation may impact the larger economy. New analysis and indicators contribute to answering some of the following questions: is the space sector still a driver for innovation in the 21st century? What are the determinants for an innovative space sector? And what are the policy responses to encourage and harness better space-related innovation?

Policy-makers have an important role to play in determining how space innovation will benefit their economies and their citizens. Some concrete steps forward include:

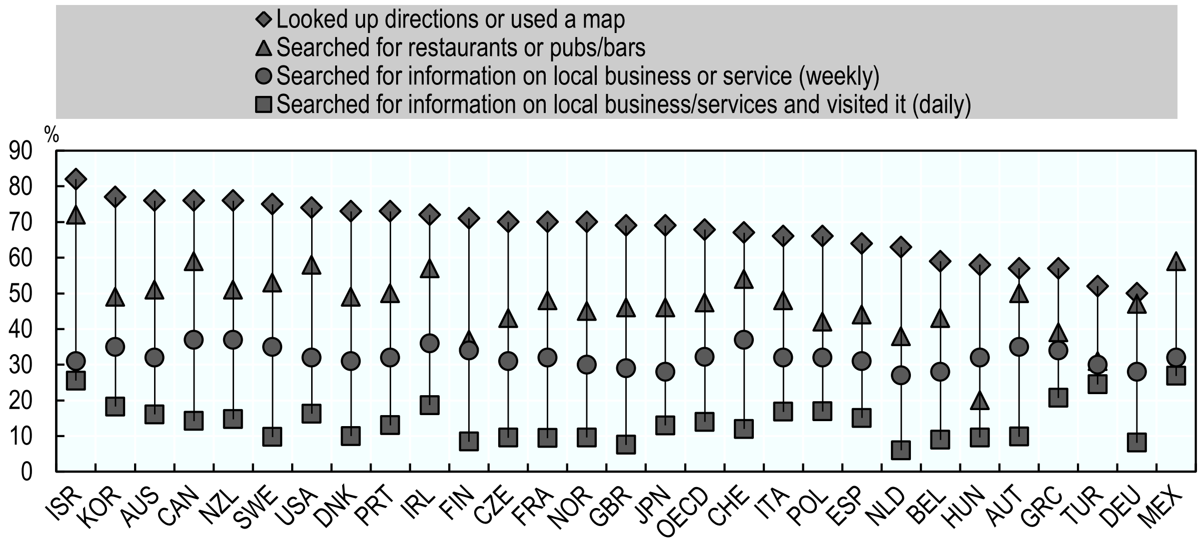
- Review and evaluate national policy instruments that support space innovation, with particular attention to examining the networks of knowledge diffusion, such as clusters and incubators, to ensure complementarity at regional and national levels.
- Participate and map downstream space activities: all countries and firms have the opportunity to participate and benefit from space innovation trends, but this situation puts new competitive pressures on governments to adopt reforms that enable start-ups and innovative firms to find or to retain niches in which they may make the most of their capabilities. This includes mapping the many actors along the value chains in national space economies.
- Capture spin-offs and technology transfers: Although their importance as outputs of space missions or programmes should not be exaggerated, significant outcomes from government-funded space research consist of space technology transfers leading to the development of new commercial products and services in various economic sectors (e.g. transport, health, environment), and the creation of spin-off companies. Governmental agencies should document these outcomes of space programmes.

A conservative sector, but still a source of major innovation

The space sector has, over the years, contributed to major scientific advances (e.g. discovery of the ozone hole, global monitoring of sea-level rise), developed revolutionary technologies (e.g. accessing space, rovers on Mars, living in space) and even diffused innovations to different sectors via technology transfers (e.g. satellite radar instruments used in medical radiology). At the same time, the sector has been risk adverse in some respects, since space systems need to be reliable and durable, sometimes stifling further innovations in the space sector itself. This paradox makes long-term fundamental research and development still critical to enabling breakthroughs for future space activities and generating new applications.

One very recent dynamic and transformative factor is the (r)evolution in downstream space applications, attracting new governmental and commercial entrants at both ends of the space sector's value chains (from satellite and rocket manufacturing to satellite services). This growing attractiveness of space comes in part from the generalisation and worldwide availably of satellite positioning, navigation and timing signals; telecommunication and broadband connections in isolated locations and on mobile platforms (smartphones, ships at sea, aircrafts) and growing access to satellite imagery. In particular, satellite navigation and positioning technologies with location-based services have been witnessing in recent years a very wide diffusion, with receivers found in all kinds of electronic devices for everyday use, such as mobile phones, personal digital assistants, cameras, portable PCs or wristwatches (Figure 1). The cheap and fast access to these applications is opening several new business opportunities to developers, but also benefiting people everywhere in the world thanks to the integration of additional services in a single interface.

Figure 1. Use of location-based services on smartphones, 2013



Source: Adapted from OECD (2015), *OECD Digital Economy Outlook 2015*, http://dx.doi.org/10.1787/9789264232440-en.

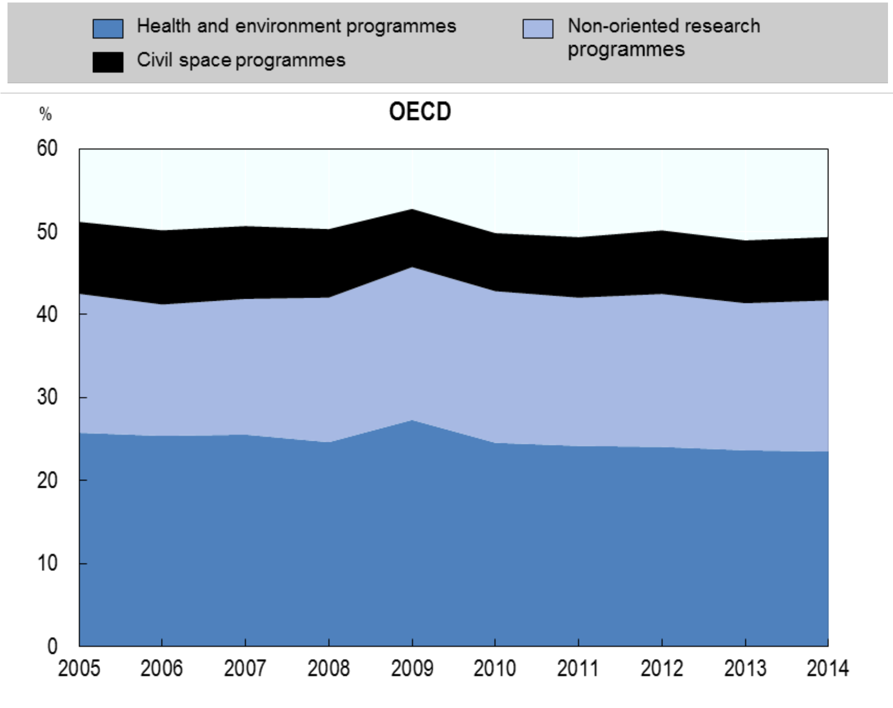
Satellite capacities combined with advances in miniaturisation, computer processing power and analytics are leading to innovation in products and services like never before. Small and large entrepreneurs in particular, some of them coming from the Internet economy, are bringing new ways of doing things in space (e.g. new industrial processes) and compelling the traditional space industry and governmental agencies to adapt to a new environment. Innovative and sometimes baffling uses of satellite signals and data by small businesses are also contributing to the creation of new commercial activities far removed from the traditional space sector, although they often rely on the satellite infrastructure (e.g. the successful Pokemon Go smartphone application uses satellite positioning).

What are the conditions for an innovative space sector?

Actors in space innovation: Although national situations differ, a variety of actors are involved in the creation and diffusion of knowledge in the space sector. Investment in science and basic research play a key role in innovation systems by providing new knowledge and pushing the knowledge frontier. The higher education system is the predominant actor in basic research, undertaking three-quarters of total basic research in OECD economies. Business enterprises play a significant role in space programmes in many countries; however, public institutions and universities still provide the foundations for future space innovation in a majority of economies and rely on sustainable institutional support. Start-ups are particularly active in downstream space applications and are often quite detached from the traditional space industry.

Figure 2. Shares of public R&D budgets for space and other selected socio-economic objectives

% of civil Government budget allocations for Research and Development (GBARD), OECD average



Source: OECD (2016), *Space and Innovation*, http://dx.doi.org/10.1787/9789264264014-en.

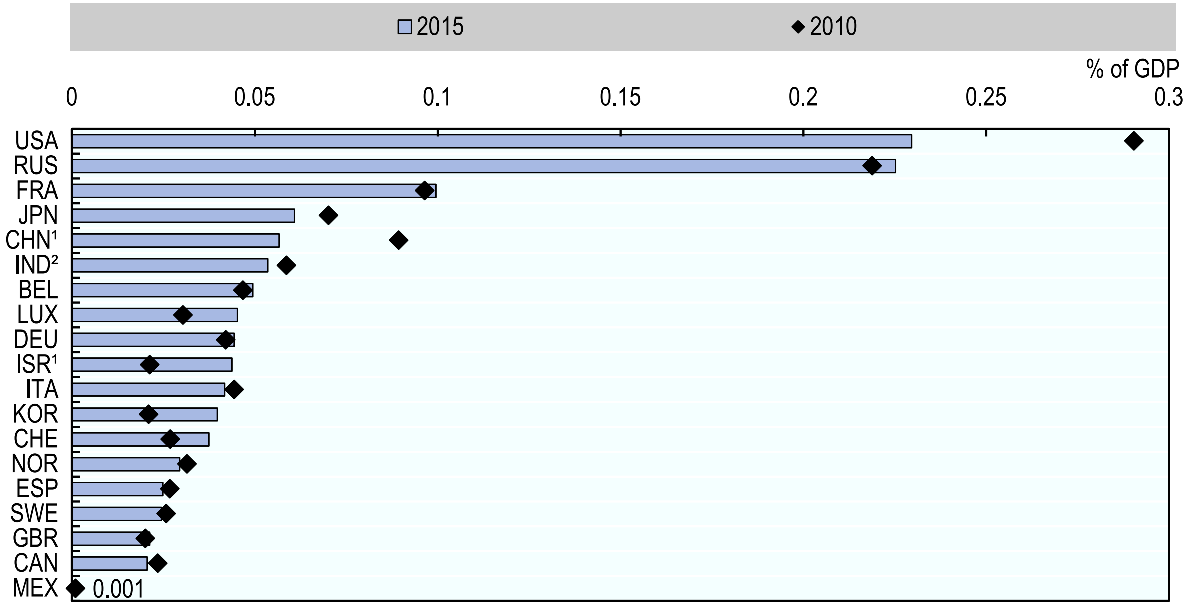
Financing space innovation: Governments are the main funders of science and long-term R&D, as well as the leading customers for many space-related products and services. Governmental support therefore forms the bulk of funding for space innovation, with a diversity of policy instruments available, such as grants, procurement, loans and tax incentives. As an indicator of public investment, government budget allocations for R&D (GBARD) data are assembled by national authorities and classified by "socio-economic objective". These diverse objectives represent the intention of the government at the time of funding commitment. Although the data provide only a partial picture of space R&D investments, the long term time series provide useful trends on policy orientations (Figure 2). Civil space R&D programmes accounted for about 8% of total OECD government R&D budgets (excluding defence) in 2014. Examining total institutional budgets for space activities (not only R&D), space investments in most economies are still modest in view of other much wider governmental programmes (e.g. health, social security). The government budget dedicated to space in the United States and the Russian Federation accounted for slightly more than 0.2% of GDP in 2015, preceding France with 0.1% and Japan with 0.06% (Figure 3). Private sources of investment (seed funding, venture capital, private equity) for some innovative space ventures have been growing, although the amounts still pale as compared to public funding. Crowdfunding is also a new financing mechanism that is growing rapidly. Although seldom used in the space sector until recently, some students now raise funds online to develop their own very small satellite projects.

Challenges and prizes: Used in many sectors, challenges and prizes are a relatively recent set of tools to stimulate innovation and entrepreneurship in the space sector. These prizes are multiplying around the world, and are funded by governmental agencies or private organisations, or jointly. Some of the prizes' objectives, such as the challenge of landing a commercial rover on the Moon by the end of 2017, are not only attracting entrepreneurs and media attention, but are also motivating the established industry.

Infrastructures and platforms enabling knowledge flows have become essential instruments to spur space innovation. Clusters, incubators and other platforms of co-operation play an important role in fostering interactions between very diverse actors, and are accelerating the growth and success of entrepreneurial companies. In this context, the uses of public testing services and facilities by diverse governmental, academic and commercial actors often remain key for technology prototype development and flight qualification.

Figure 3. Selected government space budget estimates

As a share of GDP, based on national currencies (current)



1. Estimates. 2. Based on preliminary budget estimates for the fiscal year 2015-16.

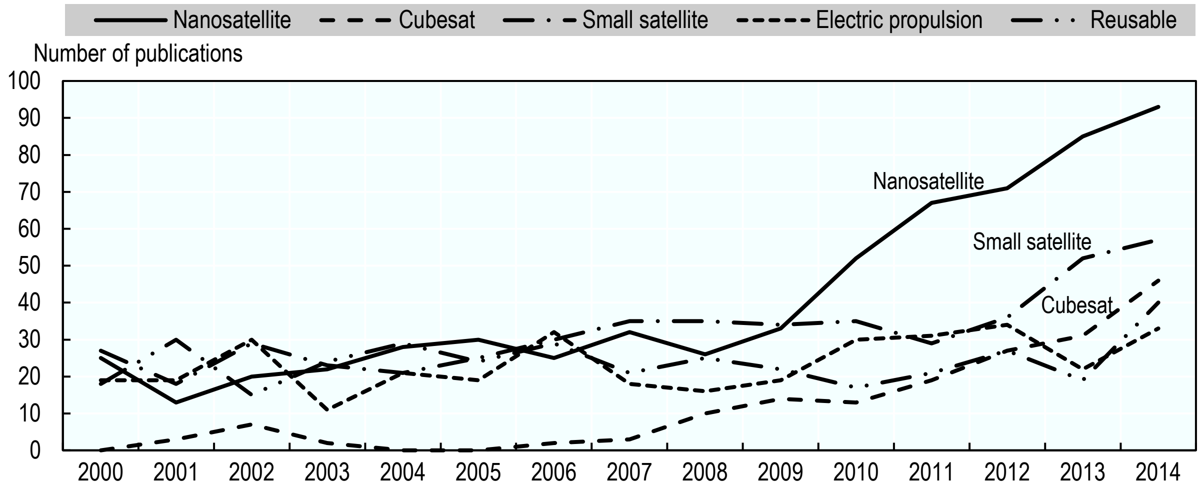
Source: OECD (2016), *Space and Innovation*, http://dx.doi.org/10.1787/9789264264014-en.

What are the drivers of space innovation?

Three overarching thrusts are driving innovation in the space sector and will probably continue to do so over the next decade: a) the persistence of national security and science objectives (with ever-more countries investing in space programmes); b) the expansion of downstream space applications; and c) the pursuit of human space exploration. Under these broad overarching objectives, recent innovations in the space sector are driven by evolutions in industrial processes (advanced manufacturing, new digitisation processes, miniaturisation), often hard-pressed by new commercial entrants, and new technological developments (space propulsion, composite materials).

A preliminary map of space innovation can be drawn by examining the scientific space literature and patents. Key sources of innovation can be identified like small and very small satellites (including cubesat and nanosatellite), electric satellite propulsion, reusable technologies for launchers and satellite navigation applications to name a few. The volume of publications dedicated to these "hot topics" is growing within the existing space literature (Figure 4). Small and very small satellites show a strong upward trend, although the absolute number of publications remains low in the conservative space literature dataset (less than 100 publications per year).

Figure 4. Selected hot topics in space literature

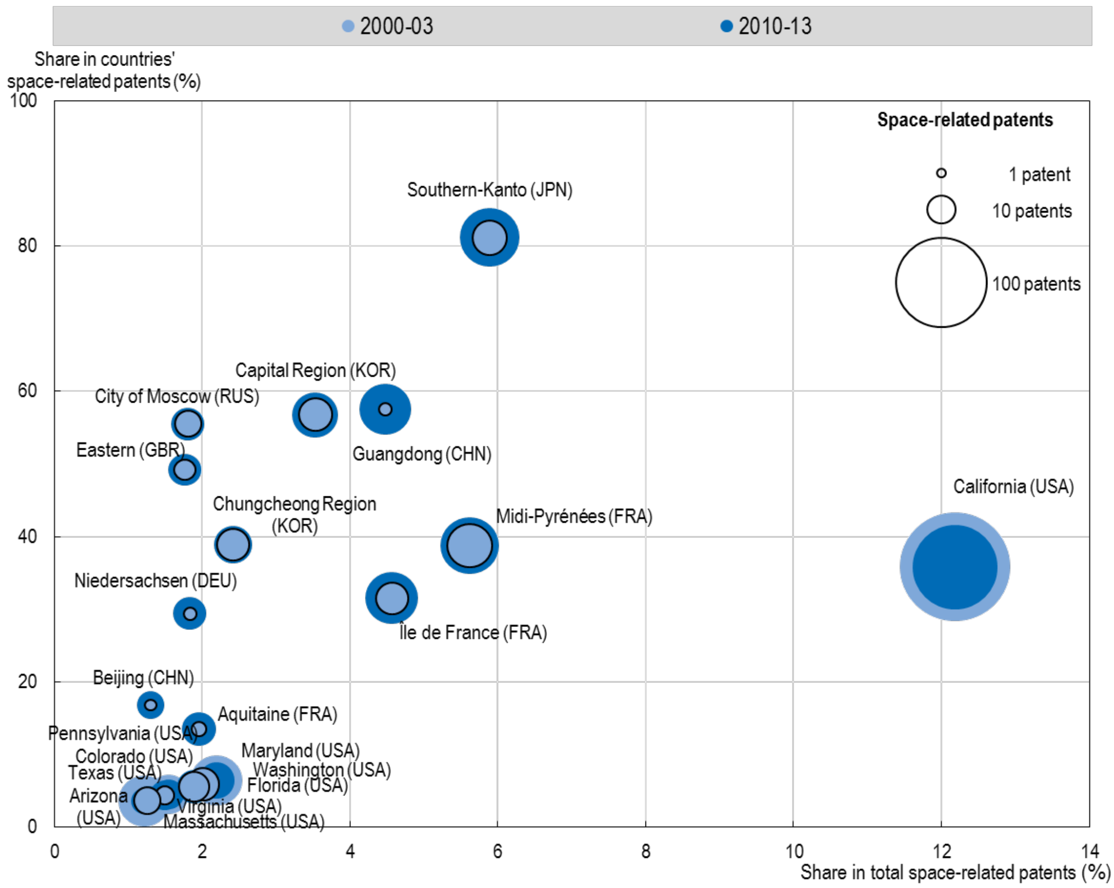


Source: OECD (2016), *Space and Innovation*, http://dx.doi.org/10.1787/9789264264014-en.

The increasing importance in scientific publications of satellite navigation systems and their many derived location-based and timing services can also be traced to recent patenting activities by commercial actors, demonstrating again that much innovation occurs today in downstream space activities. Patenting in the space sector is not as common as in other sectors, as commercial discretion and institutional confidentiality are often still priorities for some space systems and applications. There are only a few hundred patents a year. Still, the number of satellite-related patents has almost quadrupled in 20 years, with more patenting occurring in different parts of the world (Figure 5).

Figure 5. Top 20 regions in space-related patents

Patent applications filed under the Patent Co-operation Treaty by inventor's residence and priority date



Source: OECD (2016), *Space and Innovation*, http://dx.doi.org/10.1787/9789264264014-en.

When exploring technological trends and the potential of space innovation for the next two decades, the space sector seems to be on the verge of starting a new cycle in its development (Table 1). This cycle could be characterised by the ever-growing uses of satellite infrastructure outputs (signals, data) to meet societal challenges, like helping bridge the digital divide and contributing to mitigate climate change with global satellite monitoring. But in parallel, innovative mass-market products using satellite capacities could be on the horizon (Figure 6), building on advances in machine to machine networking, and real-time and adaptive systems.

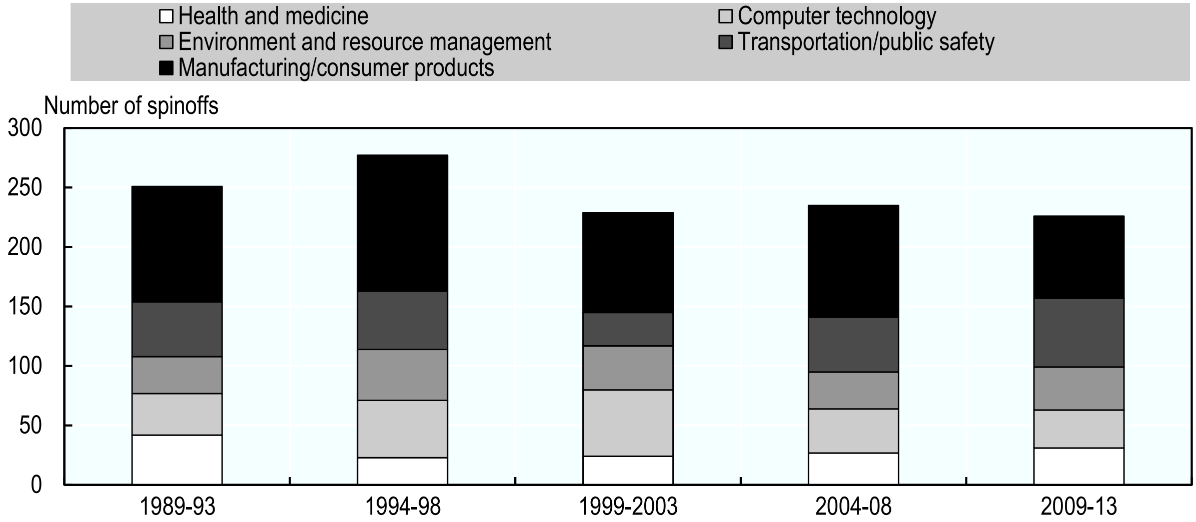
On the space segment, new generations of smart-satellites and orbital space stations are expected, while a number of commercial space activities could be coming of age (e.g. new human-rated space launchers, in-orbit servicing). A more extensive mapping of our solar system and beyond is also already anticipated thanks to new telescopes and robotic missions in development and planned for the next decade.

Table 1. Cycles of development in the space sector

Established		**Emerging**
Pre-space age "-1"	1926-42	First rockets (from Goddard to the V2)
Pre-space age "0"	1943-57	Military race for intercontinental ballistic missiles, first satellite in orbit (i.e. Sputnik)
Cycle 1	1958-72	Space race (from Sputnik to the end of the Apollo era), beginning of military applications (e.g. spy satellites), humans in space, robotic space exploration
Cycle 2	1973-86	First space stations (Skylab, Salyut) and shuttles (US space shuttle, Buran), further development of military applications (GPS, Glonass), beginning of civilian and commercial applications (Earth observation, telecommunications), emergence of new actors (Europe, People's Republic of China, Japan)
Cycle 3	1987-2002	Second generation of space stations (Mir, ISS), stronger role of space applications in militaries, strong development of civilian and commercial applications
Cycle 4	2003-18	Ubiquitous use of space applications in various fields thanks to digitalisation (rise of downstream activities), new generation of space systems (small satellites) prompted by integration of breakthroughs in micro-electronics, computers and material sciences, globalisation of space activities (large and very small national space programmes coexist, development of global value chains)
Cycle 5	2018-33	Growing uses of satellite infrastructure outputs (signals, data) in mass-market products and for treaties' global monitoring, third generation of space stations, extensive mapping of solar system and beyond thanks to new telescopes and robotic missions, new space activities coming of age (e.g. new human-rated space launchers, in-orbit servicing)

Source: Adapted from OECD (2004), *Space 2030: Exploring the Future of Space Applications*, http://dx.doi.org/10.1787/9789264020344-en.

Figure 6. NASA spin-offs in different sectors



Source: OECD (2016), *Space and Innovation*, http://dx.doi.org/10.1787/9789264264014-en.

What are the policy responses to better monitor and encourage space innovation?

Policy-makers will have an important role to play in determining what the space sector will look like in the coming decade. Some concrete steps forward include:

1. **Review national policy instruments that support space innovation**: the policy instruments that support the development of innovative space activities are often those used for supporting innovation in different high-tech domains (e.g. grants, loans, export credits), but some are more specific to space (e.g. procurement mechanisms, prizes). As national situations differ widely, governments looking to support space innovation trends should review and evaluate existing instruments to determine those most promising with respect to their space programme's objectives. Particular attention should be paid to examining the networks of knowledge diffusion, such as clusters and incubators, to ensure complementarity at regional and national levels.
2. **Participate in downstream space activities**: all countries and firms have the opportunity to participate and benefit from the space sector's global value chains, but this situation puts new competitive pressures on governments to adopt reforms that enable start-ups and innovative firms to find or to retain niches in which they may make the most of their capabilities. In this context, governments that fund space programmes should better track who is doing what in the space industry and beyond, via regular industry surveys and analysis of existing administrative data. This includes mapping the many actors along the value chains in their national space economy.
3. **Capture spin-offs and technology transfers**: significant outcomes from government-funded space research have consisted of space technology transfers leading to the development of new commercial products and services in various economic sectors (e.g. transport, health, environment), and the creation of spin-off companies. Agencies should systematically examine and track the spin-offs and technology transfers to other sectors that are derived from space investments. NASA registered and documented about 2 000 commercial products and services successfully developed since 2000, with the majority recorded in the sectors of computer technology, environment, resource management, and health and medicine (Figure 6). Although their importance as outputs of space missions or programmes should not be exaggerated, they constitute useful pointers. The *Space Agencies Technology Transfer Officers* group, recently established to exchange best practices, is a positive step in that direction.

Further reading

OECD (2016), *Space and Innovation*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264264014-en.

OECD (2014), *The Space Economy at a Glance 2014*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264217294-en.

Website

OECD Space Forum, https://www.innovationpolicyplatform.org/oecd-space-forum.

Directorate for Science, Technology and Innovation Policy Note

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