



## CSIRO Submission 20/741

### Parliamentary Inquiry into Developing Australia's Space Industry

### Standing Committee on Industry, Innovation, Science and Resources

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## Executive Summary

CSIRO has over 75 years of space science experience and operates a range of facilities, research programs and industry development activities that support and contribute to the development of the Australian space industry, including:

- National space facilities
- CSIRO Space Technology R&D Program (Future Science Platform)
- CSIRO Centre for Earth Observation
- AquaWatch Australia Mission
- Space 2.0 Workshop series
- Public outreach, education and training activities.

This submission addresses each of the Inquiry's Terms of Reference and provides information about CSIRO's science and technology activities directly related to the space industry and its development. This includes activities relating to operating in space (including the development, support and undertaking of, or derivation of information or resources from, such operations) and/or understanding the space environment for the purposes of operating in space. CSIRO's astronomy related activities are not included in this submission.

In addition, the submission seeks to highlight the importance of space science and the need for a long-term national space program. The main points on each of these are:

- **The importance of space science**

Internationally, many leading space agencies have significant space science programs, including the scientific and exploratory missions led by NASA's Jet Propulsion Laboratory and the Earth observation programs of many international space agencies. Science-directed missions not only expand our knowledge of Earth and the space environment, they also drive cutting-edge technology development, grow industry, encourage international collaboration, and inspire the future STEM workforce.

Ongoing support for the space science sector is critical to the long-term competitiveness of the Australian space industry. The Australian Space Agency does not currently have a science-specific program, although it has funded some science activities that are driven by industry growth.

Increased national investment in low Technology Readiness Level (TRL) space-related research and Government-level coordination of a space science program would provide a significant boost to this underpinning element of the Australian space sector. This is a role that could be added to the remit of the Australian Space Agency or taken up by CSIRO as part of its wider role as the national science agency.

- **The need for a long-term national space program**

The Australian Government, particularly the defence portfolio, is currently the primary Australian customer for space capability. Long-term investment by the Australian Government in a program of national space missions would be an effective way to support and grow a sustainable national space capability. Economies of scale and the timelines involved in space missions mean that investment in only a single space mission is not sufficient to catalyse and sustain a competitive national space industry; instead, a long-term pipeline of opportunities is required.

CSIRO is available to discuss this submission further with the Committee. Please refer to the contact details on the cover page.

# 1 Introduction

CSIRO is pleased to offer input to the Parliamentary Inquiry into Developing Australia's Space Industry.

CSIRO is an independent statutory authority constituted and operating under the provisions of the *Science and Industry Research Act 1949*, and has functions to:

- a) conduct scientific research to benefit Australian industry and the community, and to contribute to the achievement of national objectives
- b) encourage and facilitate the application of the results of scientific research
- c) manage and make available national facilities for scientific research
- d) contribute to scientific collaboration between Australia and other countries, and
- e) contribute to training the next generation of Australian researchers.

In regard to space, CSIRO has over 75 years of space science experience and proven capabilities including:

- Space engineering and technologies
- Satellite operations and data applications, particularly Earth observation
- Space communications
- Space science and radio astronomy
- Space education and outreach
- Commercialisation and space industry development.

Alongside these, CSIRO has capabilities in research areas that can support Australia's space activities, such as:

- Robotics
- Data analytics, artificial intelligence and machine learning
- Advanced manufacturing
- Energy
- Mineral resources and autonomous mining technologies
- Agricultural production systems and oceanic research
- Health and biosecurity.

CSIRO operates several national space facilities: the Canberra Deep Space Communication Complex (for NASA), the European Space Agency's New Norcia deep space tracking station, and the CSIRO share of the UK-operated NovaSAR-1 satellite.

CSIRO is currently developing its first CubeSat, CSIROSat-1, scheduled for launch in 2021-22.

CSIRO developed a national space industry roadmap, which was released in September 2018. It is available online from: <https://www.csiro.au/en/Do-business/Futures/Reports/Future-Industries/Space-Roadmap>.

## 2 Responses to Inquiry Terms of Reference

This section outlines CSIRO's activities related to the Committees Terms of Interest, and how these activities support Australia's space industry.

### 2.1 Development of space satellites, technology and equipment

CSIRO's newest and largest space program, the Space Technology Future Science Platform ("Space FSP") was established in 2018-19 with an initial investment of \$16 million, specifically to generate technological innovations that will support the growth of the Australian space industry. This investment has already been

leveraged to increase the total program value to more than \$24 million, and in the coming years this will grow further, including through expanding external research and industry partnerships.

Through this multidisciplinary Space FSP program CSIRO carries out a wide range of space technology research and development activities in areas including small satellite technologies (such as sensors, power systems and materials), Earth observation data analytics and applications, space communications, space object tracking and signal processing, robotics, remote operations and in situ resource utilisation, and space life sciences. This program is developing capability within CSIRO and generating new innovations that hold the potential to generate significant societal benefits and commercial opportunities and, in partnership with industry, will help transform the Australian space sector.

CSIRO has operated the Canberra Deep Space Communication Complex as part of NASA's Deep Space Network for over 50 years. Since 2018-19 CSIRO has also provided operational and maintenance support for the European Space Agency's (ESA) deep space tracking station at New Norcia, WA. These facilities form the cornerstone of deep space communications capabilities in Australia and underpin our international space relationships. Furthermore, CSIRO's expertise in deep space communications is being combined with research into high-frequency, high-bandwidth communications technologies like Terahertz and optical communications, and development of communications equipment derived from our radio astronomy facilities and technology like phased arrays, to create new space communications technologies and equipment which can be leveraged by the Australian space industry.

CSIRO operates the Australia Telescope National Facility (ATNF), which includes the Parkes, Australian Square Kilometre Array Pathfinder (ASKAP) and Australia Telescope Compact Array radio telescopes. While these are primarily radio astronomy facilities, the ATNF and CDSCC facilities are also used to undertake space science research, including space domain awareness and asteroid tracking activities. Studying asteroids can provide insight into the formation of the solar system, but near-Earth objects can also present a hazard to Earth. Asteroids emerging from the southern hemisphere, which account for 5–10 per cent of all Near Earth Asteroids, are not immediately detectable by the international NASA Near Earth Asteroid (NEA) program. Australia is contributing to this NASA program as well as developing new science to assist future space exploration missions by combining the capabilities of CDSCC and the ATNF (Compact Array and Parkes radio telescopes) to perform bistatic radar tracking of asteroids. Since 2015 CSIRO, in collaboration with NASA JPL, has demonstrated the successful detection and tracking of seven Near Earth Asteroids with diameters of 0.02–2 km at ranges of 0.1 to 10 lunar distances using exclusively Australian-based systems. CSIRO also operates the Murchison Radio-astronomy Observatory (MRO), which will be home to the Square Kilometre Array (SKA) radio telescope, and which already hosts the Murchison Widefield Array (MWA) radio telescope. The MWA contributes to space science research and the SKA is anticipated likewise to contribute.

CSIRO has had world-leading expertise for decades in satellite Earth observation, including data quality assurance, calibration and validation, data analytics, and applications development. CSIRO directly applies its Earth observation capabilities to areas of national benefit including climate and disaster monitoring, managing our water and natural resources, monitoring the environment, and supporting public access to and use of petabyte-scale Earth observation datasets through the development of "Data Cube" data analytics platforms. CSIRO jointly developed the Australian Geoscience Data Cube platform technology with Geoscience Australia and the National Computational Infrastructure (NCI); this underpinned the development of Digital Earth Australia, operated by Geoscience Australia. CSIRO operates the Earth Analytics Science and Innovation (EASI) data analytics platform and industry hub and has assisted in the development of regional Data Cubes with international partners. Data Cubes provide the digital infrastructure to facilitate Earth observation data discovery and integration, and enable governments and industry, including SMEs, to undertake scalable and low start-up cost data analysis to develop new business products.

CSIRO also contributes technical and coordination expertise in Earth observation to national and international policy matters, for example contributing to the 2020 Bushfire Earth Observation Taskforce led by the Australian Space Agency, and developing international guidelines to support the use of Earth observation information for informing progress towards the United Nations (UN) Sustainable Development Goals.

Additionally, the acquisition by CSIRO of a 10 per cent tasking and downlink capacity share of the UK-operated NovaSAR-1 satellite was a significant innovation in the provision of national space facilities for Australia (a \$10m investment). The satellite was successfully launched in September 2018 and provides the very first opportunity for Australian scientists to directly task and acquire imagery in near-real-time from an Earth observation satellite, for applications ranging from disaster monitoring to land use and land cover mapping. In addition, this satellite provides the only source of S-band Synthetic Aperture Radar imagery currently available worldwide, providing Australian researchers with the opportunity to develop unique scientific innovations utilising this data type. CSIRO will operate the NovaSAR-1 satellite as a national research facility, providing free open-access Earth observation data for the benefit of the Australian research community, with researchers from across the country able to apply for data to be acquired by this facility.

CSIROSat-1, CSIRO's first satellite, is a 3U<sup>1</sup> CubeSat currently under development with Australian space start-up company Inovor Technologies. It is primarily a research platform but also provides opportunities for Australian industry. The project supports our industry partner to realise commercial benefit by securing spaceflight heritage for their hardware and bus-related sub-systems. Additional potential commercial opportunities may also arise from the successful demonstration of new imaging and data processing technologies being developed by CSIRO for the mission. This will complement the provision of Earth observation imagery and data services being developed by CSIRO, particularly in relation to NovaSAR-1 and Data Cube technology.

CSIRO is developing AquaWatch Australia as part of its emerging Missions portfolio, in partnership with the SmartSat CRC and other organisations. The aim of this Mission is to establish an integrated ground-to-space national water quality monitoring system to provide decision-ready information to water agencies, local communities, agricultural and commercial water users, in order to support better management of our valuable freshwater resources, manage the health of ecosystems and coastal resources, and prevent human or animal health impacts. The Mission aims to include three key elements that will be developed over the course of the next decade: one or more locally built Earth observation satellites, combining their data with a dense network of ground sensors, strategically placed throughout our nation's rivers and waterways, into a system that provides water quality observations and predictions and data for decision making. This Mission, established by CSIRO and the SmartSat CRC, is working closely in collaboration with the local space industry to create more high-tech space jobs, and at the same time solve a major environmental challenge for Australia. A 'Phase 0' study is underway in 2020-21 to undertake user consultations and develop the Mission's business case.

## **2.2 International collaboration, engagement and missions**

International collaboration enables all of CSIRO's national space facilities including CDSCC (NASA), the New Norcia tracking station (ESA) and NovaSAR-1 (UK), and is critical to ensuring continuity of satellite data access for Australia. International engagement and collaboration also provide opportunities to access and contribute to space missions of scale and drive domestic innovation.

<sup>1</sup> CubeSats are small modular satellites built from one or more units (U) of standard dimensions 10x10x11.35 cm. A 3U CubeSat comprises three such standard units.

CSIRO has two key operational agreements with NASA: the *Agreement between the Government of Australia and the Government of the United States of America concerning Space Vehicle Tracking and Communication Facilities*, under which it manages the Canberra Deep Space Communication Complex (CDSCC); and the *Agreement between the Government of Australia and the Government of the United States of America concerning the Conduct of Scientific Balloon Flights for Civil Research Purposes*, under which it manages the NASA Alice Springs Ballooning Facility. As part of the NASA Deep Space Network, CDSCC will support the Lunar Artemis mission planned for 2024.

CSIRO provides operations support for the ESA deep space tracking station at New Norcia, WA. CSIRO also has agreements with other international space agencies, such as the *CSIRO-JAXA Collaborative Agreement for the Conduct of Scientific Balloon Flights for Civilian Research Purposes (2017)* with the Japanese aerospace Exploration Agency (JAXA).

CSIRO, along with the Australian Space Agency, is a member of the International Space Exploration Coordination Group (ISECG) and International Mars Exploration Working Group (IMEWG) and contributes to concepts and technical input for the exploration of space in coordination with the international space community.

Following the 2019 statement of intent between the Australian Space Agency and the UK Space Agency to establish a UK-Australia 'Space Bridge', CSIRO worked with the UK Space Agency and other international partners to design projects that will use space technology to deliver sustainable benefits to Pacific Island countries vulnerable to climate change and natural disasters.

CSIRO jointly with Geoscience Australia, represents Australia on key programmatic aspects of international coordination on Earth observations from space. CSIRO serves as the Australian principal on the international Committee on Earth Observation Satellites (CEOS), co-leading a number of working groups and teams. CSIRO, along with Geoscience Australia and the Bureau of Meteorology, is a member of the Australian Government delegation to the inter-governmental Group on Earth Observations (GEO) and serves as the CEOS Representative on GEO Executive Committee.

Over 140 government programs, state and federal, and associated stakeholders, rely on unencumbered access to satellite-derived Earth observation data to address areas of national benefit including climate and disaster monitoring, managing our water and natural resources, and monitoring the environment <sup>2</sup>. Australia does not currently own its own Earth observation satellites, and engagement in these collaborative international forums as well as provision of services like satellite calibration and validation to our international partner agencies are critical to supporting the relationships that ensure Australia is able to access data from international Earth observation satellites.

### **2.3 Commercialisation of research and development, including flow on benefits to other industry sectors**

CSIRO's value to the Australian economy is enormous. CSIRO's innovations include the Wireless LAN technology that is most commonly used to enable fast Wi-Fi, as well as Aerogard and polymer banknotes, and today extend to breakthroughs like growing gluten-free grains and 3D-printing body parts. The estimated present value of benefits from all of CSIRO's work is around \$4.5 billion per year (more than four times the funding provided by the Australian Government).

In 2018-19, CSIRO worked with 1750 private industry customers, including 400 major Australian companies, more than 1060 Australian small to medium enterprises (SMEs), and 280 overseas corporations.

<sup>2</sup> "Australian Government Earth Observation Data Requirements to 2025", report prepared by the Cooperative Research Centre for Spatial Information for Geoscience Australia and the Bureau of Meteorology, 2016, [https://d28rz98at9flks.cloudfront.net/83102/83102\\_EOS\\_Report.pdf](https://d28rz98at9flks.cloudfront.net/83102/83102_EOS_Report.pdf)

With more than 1800 patents, we are Australia's largest patent holder. This ever-increasing wealth of intellectual property is a vast source of commercial opportunity and has already resulted in more than 150 spin-off companies.

CSIRO has national reach and presence, with 55 sites across Australia, and can leverage an extremely broad range of multidisciplinary expertise and applications in the development of new value-added space capabilities. We also have many well-established domestic and international relationships which can be leveraged for the benefit of our partners and the nation.

As a national research agency, CSIRO is able to invest in public good applications, and to support industry development through exploratory innovation by investing in very low Technology Readiness Level (TRL) activities with a higher risk profile than industry would generally be willing to support alone.

CSIRO is also able to offer a wide range of industry support mechanisms, as well as commercial engagement strategies to enable industry and national benefit from CSIRO research. CSIRO's SME Connect program facilitates and enables innovation-driven partnerships between CSIRO and industry through funding, support and resources. Main Sequence Ventures, which manages the CSIRO Innovation Fund, provides venture capital for Australian deep-tech companies, including space start-ups Gilmour Space Technologies, FluroSat and Myriota.

CSIRO also supports the development of the Australian space industry, particularly start-up companies, through initiatives such as:

- hosting the CSIRO Space 2.0 Workshop series
  - During 2017 and 2018 CSIRO held three Space 2.0 workshops to support opportunities for Australian space start-ups and SMEs to develop research and business collaborations with CSIRO and the wider research and government sectors, aerospace primes, investors and space technology end-users.
  - The fourth Space 2.0 Workshop (2019) was run jointly by CSIRO and the Australian Space Agency. It brought together the Australian space 2.0 ecosystem stakeholders to discuss opportunities for large-scale national space activities that would contribute to the goals and priority areas of the Australian Space Agency. A key outcome of this workshop was the development of the AquaWatch Australia concept, which was subsequently taken forward by CSIRO and the SmartSat CRC. The most recent workshop, also run jointly by CSIRO and the Australian Space Agency, focused on national and international space supply chains and opportunities for the manufacturing sector specifically.
  - The Australian Space Agency has indicated that they believe the collaborative engagements facilitated and encouraged by the Space 2.0 series of workshops have helped to facilitate a higher quality of collaborative grant applications from the Australian space industry under the Agency's funding programs.
- collaborating with industry on projects such as CSIROSat-1 to assist Australian companies to demonstrate space qualification and achieve spaceflight heritage and enable commercial growth
- being a Supporting Participant in the SmartSat CRC and engaging with CRC industry representatives on development of the AquaWatch Australia Mission.

## **2.4 Future research capacity, workforce development and job creation**

CSIRO promotes space-related science, technology, engineering and mathematics (STEM) capability, development and education, facilitates the use of scientific research and supports the development of the space industry through a number of channels.



### **2.4.1 Public outreach and education programs**

CSIRO has unparalleled public outreach and education programs in support of its space capabilities, which connect with, inspire and educate audiences spanning industry, professionals in the field, the general public and students. CSIRO operates visitors' centres at the Parkes radio telescope and CDSCC, and together these two sites attract more than 150,000 public visitors each year, inspiring students and families to understand astronomy and space sciences. In 2018-19 CSIRO's public outreach activities included an extensive program of activities in support of the 50<sup>th</sup> anniversary of the Apollo 11 Moon landing, ranging from sponsoring Apollo 11 exhibitions at Questacon and the Powerhouse Museum, Sydney, and donating the only official copy of the Apollo 11 Moon landing footage held outside the US to the National Film and Sound Archive, to working with the Royal Australian Mint on the packaging and promotion of commemorative coins, and hosting public open days at CDSCC and the Parkes radio telescope. These open days attracted 24,000 visitors including the US Ambassador to Australia and the Minister for Industry, Science and Technology, as well as the Deputy Prime Minister.

CSIRO's Education and Outreach programs deliver innovative learning opportunities to schools, teachers and the wider community, including delivery of NASA's Global Learning and Observations to Benefit the Environment (GLOBE) program in partnership with the Australian Space Agency, and train the next generation of STEM professionals. CSIRO Publishing builds awareness and appreciation and shares knowledge through scholarly and general publishing.

### **2.4.2 Future directions, research capability and workforce development**

In September 2018 CSIRO released a national space industry roadmap<sup>3</sup>, to identify major challenges over the coming decades and opportunities where Australia can potentially develop world-leading expertise and realise industry growth. The Space Roadmap also helped inform the development of the National Civil Space Priorities released April 2019.

As Australia's national science agency, a key role of CSIRO is fostering the development of future national research capacity, particularly through postdoctoral fellowships, joint postgraduate studentships with universities, undergraduate internships and work experience programs for school students. Growing future research capacity and workforce development is also a key goal of the SmartSat CRC, of which CSIRO is a Supporting Participant.

Development of national space capability is a key goal of CSIRO's Space Technology FSP program. In addition to any commercial opportunities that may arise in future from technological developments and subsequent industry partnerships, all projects under this program also feature education and capability development elements, including providing opportunities for postgraduate students and postdoctoral researchers.

As outlined in earlier sections, CSIRO is also providing Australian researchers with opportunities to develop new world-leading S-band SAR Earth observation capabilities by investing in a capacity share of the UK-operated NovaSAR-1 satellite. This capacity share will be operated by CSIRO as a national facility, with free access to data for Australian researchers.

<sup>3</sup> "Space: A roadmap for unlocking future growth opportunities for Australia", CSIRO Futures, 2018, <https://www.csiro.au/en/Do-business/Futures/Reports/Future-Industries/Space-Roadmap>

## **2.5 Other related matters**

### **2.5.1 Collaboration with the Australian Space Agency**

CSIRO has a close and important working relationship with the Australian Space Agency. Our roles are complementary and together the organisations can help develop the space industry and Australia's international role in space.

CSIRO participated on the Expert Reference Group (ERG) which recommended the establishment of a national space agency and since its inception have collaborated on numerous activities including:

- supporting industry development and highlighting industry capabilities e.g. the Space 2.0 Workshops, and national and international events like the International Astronautical Congress
- supporting the operations of the Australian Space Agency through CSIRO staff secondments, provision of technical expertise (e.g. on working groups and in the development of technology roadmaps), and joint participation in international representation activities like the International Space Exploration Working Group (ISECG)
- public education and outreach activities e.g. the Apollo 11 Moon landing 50<sup>th</sup> anniversary campaign and delivering NASA's GLOBE program.

CSIRO and the Australian Space Agency are developing an MOU with joint priorities for ongoing collaboration, including on national space facilities and infrastructure, international partnerships including the Australian Government's partnership on future space cooperation with NASA, and national capability development, education and outreach.

### **2.5.2 The importance of space science**

Internationally, many leading space agencies have significant space science programs. For example, through its Jet Propulsion Laboratory, NASA has explored the outer reaches of the solar system and through the Moon to Mars program it is preparing to return humans to the Moon and to travel on to Mars for scientific and exploration purposes. Similarly, international space agencies have led the way with Earth observation satellites that are critical to our understanding and management of our planet. These science-led missions not only expand our knowledge, they also drive cutting-edge technology development, grow industry and encourage international collaboration. They also play an unparalleled role in education, attracting generations of students to STEM subjects.

Ongoing support for the space science sector is critical to the long-term competitiveness of the Australian space industry. The Australian Space Agency does not currently have a science-specific program, although it has funded some science activities that are driven by industry growth. The Australian Academy of Science's soon to be released 2021 Space Science Decadal Plan highlights how national space science capability underpins a skilled space workforce and an innovative industry. Australia's space science capabilities primarily reside within the university sector and research agencies like CSIRO; increased national investment in low Technology Readiness Level (TRL) space-related research and Government-level coordination of a space science program would provide a significant boost to this underpinning element of the Australian space sector. This is a role that could be added to the remit of the Australian Space Agency or taken up by CSIRO as part of its wider role as the national science agency.

### **2.5.3 A long-term national space program**

Government, including Defence, is currently the primary Australian customer for space capability. Long-term investment by the Australian Government in a program of national space missions would be an effective way to support and grow a sustainable national space capability. While Australia has the R&D capability to develop the technologies and products needed to achieve a competitive national space

industry and contribute to international space missions, economies of scale and the timelines involved in space missions make realising these opportunities challenging. A single space mission is not sufficient to catalyse and sustain such an industry; instead, a long-term pipeline of opportunities is required.

A program of national space missions would drive scientific, technical and industrial innovation, increase opportunities for international collaboration, and grow workforce capability and space sector growth as a whole. Many international space agencies have documented the socio-economic benefits, including economic multipliers, of investment in space science missions including NASA's Moon to Mars Program<sup>4,5</sup>.

Space technology is inherently dual-use, and a significant proportion of the space industry, particularly those parts relating to Earth observation, communications, position, navigation and timing, space domain awareness, and space launch, can equally service civilian and Defence markets. With Defence as the primary Australian customer for space capability, Australia's space capability and industry growth goals should be complementary to Defence space capability needs, particularly with regard to areas in which it would be desirable to develop sovereign capability.

#### **2.5.4 Supporting international collaboration**

As outlined in Section 2.2, international collaboration enables all of CSIRO's national space facilities including CDSCC (NASA), the New Norcia tracking station (ESA) and NovaSAR-1 (UK), and is critical to ensuring continuity of satellite data access for Australia. International engagement and collaboration also provide opportunities to access and contribute to space missions of scale and drive domestic innovation.

CSIRO works closely with Geoscience Australia and the Bureau Meteorology in support of operational Earth observation activities, and jointly with these agencies represents Australia on key programmatic aspects of international coordination on Earth observations from space, particularly through the international Committee on Earth Observation Satellites (CEOS) and the inter-governmental Group on Earth Observations (GEO). As outlined in Section 2.2, Australia relies on its international partner agencies for access to critical satellite imagery data for our national operations. It is important that Australia is adequately resourced to continue to provide support to its international partners, for example through satellite calibration and validation services, and collaborating on the development of regional satellite Data Cubes to improve accessibility and utility of satellite data, and consider enhancing this support by participating in additional cooperative initiatives in a range of areas. Such collaborations not only ensure continuity of satellite data access for Australia but provide Australia with the opportunity to influence international activities and leverage international expertise to develop new capabilities that will be beneficial in achieving sovereign space capabilities in future.

<sup>4</sup> "NASA and Moon to Mars Program Economic Impact Study", NASA, August 2020, [https://www.nasa.gov/sites/default/files/atoms/files/nasa\\_economic\\_impact\\_study.pdf](https://www.nasa.gov/sites/default/files/atoms/files/nasa_economic_impact_study.pdf)

<sup>5</sup> "Socio-economic impact of space activities", European Space Agency, Sept 2018, [https://www.esa.int/Enabling\\_Support/Preparing\\_for\\_the\\_Future/Discovery\\_and\\_Preparation/Socio-economic\\_impact\\_of\\_space\\_activities](https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/Socio-economic_impact_of_space_activities)