technopolis group

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APPENDICES: Impact evaluation of UK investment in ESA

XX

know.space

cambridge econometrics
clarity from complexity

Science-Metrix
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APPENDICES: Impact evaluation of UK investment in ESA

Technopolis Ltd, know.space, Cambridge Econometrics, Science-Metrix

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Appendix A Evaluation indicators

The tables below provide details of each of the quantitative indicators used in the evaluation. For each indicator we provide:

- Indicator name
- ToC level
- Data source(s)
- Definition
- Recommended collection frequency
- The time periods for which the data as provided in this evaluation (i.e. baseline, current position, projected position)
- Additional information / comments

A.1 Impact domain: knowledge

Indicator	No. of papers arising directly from ESA contracts			No. of ESA-related papers		Citations of ESA-related papers: FWCI	
ToC level	**OUTPUT**			**OUTCOME**		**OUTCOME**	
Data source	Survey of ESA contractors			Scopus Databases of space research such as the Smithsonian Astrophysical Observatory (SAO) Astrophysics Data System (ADS) ResearchFish		Scopus	
Definition	Papers arising directly from ESA contracts (as reported by survey respondents) that are authored or co-authored by people within the organisations that hold ESA contracts Full counting is used – this assigns all papers with at least one UK author a count of '1'			A count of: • Papers with ESA (or named ESA missions/ assets) in title, abstract, acknowledgements • Papers based on development and use of ESA assets • All papers reported via ResearchFish • UK papers in this dataset are identified as papers with at least one author affiliated to an organisation in the UK		Two citation indicators: (full definitions in Appendix xx) • Field-weighed citation impact (FWCI) Highly cited papers at 10%, 5% and 1% level (HCP10, HCP5, HCP1)	
Collection frequency	TBD[1]			Annual		Annual	
Time period provided	Baseline	Current	Projected	Baseline: 2008-2020	Current	Baseline; 2008-2020	Current
Additional information	This data only includes papers arising directly from ESA contracts. It does not include papers arising from UKSA grants to develop instrumentation for ESA missions (i.e. it does not include those reported via ResearchFish).			• Data is provided using 'full-counting' (this assigns all papers with at least one UK author a count of '1') • This indicator should pick up the papers arising directly from ESA contracts (assuming that ESA is appropriately referenced)		• A minimum of two years following the latest year of publication is required to ensure sufficient time has lapsed for a reasonable level of citations to have occurred. Therefore, papers published after 2018 are not included in these computation of this indicator • FWCI is normalised to 1 for all papers worldwide within a specific thematic domain (as defined in Scopus), in this case the space theme	

[1] The collection frequency is recorded as 'TBD' i.e. be decided as it is dependent on the frequency of a survey of UK ESA contractors. We recommend, at a minimum, every three years to align with the end of the three years of a CMIN period prior to the new commitments agreed at the subsequent CMIN e.g. Q4 2024 and Q4 2027

Indicator	Citations of ESA-related papers: HCP		International collaboration rate (ICR)		Altmetrics: citations of ESA-related papers in policy documents	
ToC level	OUTCOME		OUTCOME		OUTCOME	
Data source	Scopus		Scopus		Scopus / Overton	
Definition	• Highly cited papers at 10%, 5% and 1% level (HCP10, HCP5, HCP1)		An international co-publication is defined as any paper that was co-published by authors affiliated to organisations from at least two countries. The international collaboration rate (ICR) of a country is simply a measure of how many papers are co-published with international partners as a proportion of that country's total output. Three ICR indicators are used: • Co-publication with any other country • Co-publication with other ESA member states • Co-publication with non-ESA member states		• The share of articles cited in at least one policy document • Data and indicator reported in 3-year blocks	
Collection frequency	Annual		Annual		Annual	
Time period provided	Baseline 2008-2020	Current	Baseline 2008-2020	Current	Baseline 2008-2019	Current
Additional information	• For citation indicators a minimum of two years following the latest year of publication is required to ensure sufficient time has lapsed for a reasonable level of citations to have occurred. Therefore, papers published after 2018 are not included in these computation of these indicators • HCP is normalised to 10%, 5% and 1% within a specific thematic domain (as defined in Scopus), in this case the space theme • Data for HCP is presented in three-year time periods to ensure there are sufficient papers in each time period for a valid and robust indicator. This is particularly important for HCP1 as the number of papers to be analysed is relatively low		• International collaboration plays a different role in the research ecosystems of large and of small nations. For instance, a researcher in a small ecosystem may have no choice but to look for international partners for complementary expertise for research collaboration, whereas a researcher in a larger market may be able to find the complementary skill set without looking outside national borders • The ICR for different sub-groups of countries do not sum to 100% as any paper may have co-authors from more than one country		•	

Indicator	Altmetrics: citations of ESA-related papers in social media		Skills uplift	
ToC level	OUTCOME		OUTPUT	
Data source	Scopus / Plum X		Survey of ESA contractors	
Definition	• The share of articles cited in at least one Facebook post • The share of articles cited in at least one Twitter tweet • The share of articles cited in at least one Wikipedia article • Data and indicator reported in 3-year blocks		• % of respondents reporting a skills uplift	
Collection frequency	Annual		TBC	
Time period provided	Baseline: 2008-2019	Current	Baseline	Current
Additional information	• The bibliometric methodology in Appendix E outlined some of the limitations of altmetrics		•	

Indicator	No. of people reached by UKSA/ ESERO-UK outreach activities		No. of students enrolling on higher education courses relevant to space	
ToC level	OUTPUT		OUTCOME	
Data source	UKSA Education and Skills Team		Higher Education Statistics Agency (HESA)	
Definition	Count of people reached via ESERO & UKSA activities		• Group 1: space-specific subjects • Group 2: space-related subjects • Group 3: physical sciences, engineering and maths • (See **Error! Reference source not found.** for further definitions)	
Collection frequency	Annual		Annual	
Time period provided	Baseline	Current	Baseline: 2014/15 to 2019/20	Current
Additional information	• 2020/21 data is not yet finalised • Indicator is a measure of quantity of people engaged with and makes no assessment of depth of interaction • All outreach activities moved online in March 2020 due to the Covid pandemic. Prior to this outreach was a combination on face-to-face and online		• HESA data is collected using the academic year • HESA introduced a new classification system used for fields of study in 2019/20 which means that there is a discontinuity in the data that approximately aligns with the baseline period for the M&E study (i.e. up to 2018/19 academic year) and the CMIN19 M&E period (2019/20 onwards)	

A.2 Impact domain: prosperity

Indicator	TRL progression arising directly from ESA contracts			Technology contributing to new space infrastructures			Collaboration within ESA contracts			Patents arising from ESA contracts		
ToC level	OUTPUT			OUTPUT			OUTPUT			OUTPUT		
Data source	Survey of ESA contractors			Survey of ESA contractors			Survey of ESA contractors			Survey of ESA contractors		
Definition	Difference in TRL for technology at start of contract & current time (% expected at end of contract)			% of respondents reporting technology contributing to new space infrastructure			% of respondents reporting collaborations with other businesses / academics in UK, ESA MS and non-ESA MS			No. of patents granted (in 2-year periods)		
Collection frequency	TBD			TBD			TBD			TBD		
Time period provided	Baseline	Current	Projected	Baseline	Current	Projected	Baseline	Current	Projected	Baseline	Current	Projected
Caveats / comments	Data for survey respondents only			Data for survey respondents only			Data for survey respondents only			Data for survey respondents only		

Indicator	Licence income from patents arising from ESA contracts			Commercialisation of new products & services from ESA contracts (1)			Commercialisation of new products & services from ESA contracts (2)			New markets accessed as result of ESA contracts (1)		
ToC level	OUTPUT			OUTPUT			OUTPUT			OUTPUT		
Data source	Survey of ESA contractors			Survey of ESA contractors			Survey of ESA contractors			Survey of ESA contractors		
Definition	Value of licence income (in 2-year periods)			% of respondents reporting commercialisation of new products & services from ESA contracts			No. of products /services commercialised (in 2-year periods)			% of respondents reporting new markets accessed as a result of ESA contracts		
Collection frequency	TBD			TBD			TBD			TBD		
Time period provided	Baseline	Current	Projected	Baseline	Current	Projected	Baseline	Current	Projected	Baseline	Current	Projected
Caveats / comments	Data for survey respondents only			Data for survey respondents only			Data for survey respondents only			Data for survey respondents only		

Indicator	New markets accessed as result of ESA contracts (2)			Spin-outs arising from ESA contracts (1)			Spin-outs arising from ESA contracts (2)			Spin-outs arising from ESA contracts (3)			Spin-outs arising from ESA contracts (4)		
ToC level	OUTPUT			OUTPUT			OUTPUT			OUTPUT			OUTPUT		
Data source	Survey of ESA contractors			Survey of ESA contractors			Survey of ESA contractors			Survey of ESA contractors			Survey of ESA contractors		
Definition	No. of new markets accessed (new overseas markets, new sectors)			No. of spin-outs arising from ESA contracts			Total annual revenue of spin-outs arising from ESA contracts			Total no. of employees of spin-outs arising from ESA contracts			Total value of investment in spin-outs arising from ESA contracts		
Collection frequency	TBD			TBD			TBD			TBD			TBD		
Time period provided	Baseline	Current	Projected	Baseline	Current	Projected	Baseline	Current	Projected	Baseline	Current	Projected	Baseline	Current	Projected
Caveats / comments	Data for survey respondents only			Data for survey respondents only			Data for survey respondents only			Data for survey respondents only			Data for survey respondents only		

Indicator	Investments/ expansions of UK businesses arising from ESA contracts			Effects on R&D investment			New strategic international partnerships arising from ESA contracts			Reputational (*other broader) effects of ESA contracts		
ToC level	OUTPUT			OUTPUT			OUTPUT			OUTPUT		
Data source	Survey of ESA contractors			Survey of ESA contractors			Survey of ESA contractors			Survey of ESA contractors		
Definition	% of respondents reporting effects: UK/non-UK (**FDI**) investments in UK businesses; UK subsidiaries established; UK businesses expanded			% of respondents reporting effects on scale and content of internal R&D activities			No. of new strategic partnerships (commercial or institutional) partnerships with organisations in ESA MS (non-UK) and non-ESA MS			% of respondents reporting effects: reputation; competitiveness; reduced barriers to entry to space markets; reduced transaction costs		
Collection frequency	TBD			TBD			TBD			TBD		
Time period provided	In last 5 years			Baseline	Current	Projected	Baseline	Current	Projected	Baseline	Current	Projected
Caveats / comments	Data for survey respondents only			Data for survey respondents only			Data for survey respondents only			Data for survey respondents only		

Indicator	No. of patents in space domain (applied for/ granted)	Normalised share of papers cited in patents (NSPCP)	Investment in ESA contractors	Investment in ESA BIC incubatees
ToC level	OUTCOME	OUTCOME	OUTCOME	OUTCOME
Data source	PATSAT	Scopus/ PATSAT	Pitchbook	Pitchbook
Definition	• Patents applied for /granted to UK organisations in space domain • Patents applied for /granted by UKIPO, USPTO, EPO, and/or WIPO • Patents based on keywords and relevant patent domains • Data collated and reported into two groups: ESA contractors and all UK organisations	Proportion of papers that have been cited in at least one patent application from any of the offices covered in the PATSTAT database	Value of investments (£m) in ESA contractors: • Venture capital • Private equity • Corporate mergers/acquisitions • IPOs • Debt • Grants Report for all ESA contractors and sub-divided into companies in upstream & downstream segments For the period 2004-2021	Value of investments (£m) in ESA contractors: • Venture capital • Private equity • Corporate mergers/acquisitions • IPOs • Debt • Grants For companies that have received support from the UK DSA BIC Investments for period 2004-2021 for incubates supported from 2014-2021
Collection frequency	Annual	Annual	Annual	Annual
Time period provided	Baseline: 2008-2019	Baseline: 2008-2018	Baseline: 2014-2021	Baseline: 2014-2021
Caveats / comments	• Data is reported for patent families (patents with same technical content and patents linked to each other through priority claims) • Full counting is used where all patents with at least one UK affiliation are counted as '1' Granted patents are assigned to the year in which the application was made	• Data provided to 2018. Insufficient time has passed for papers to have been cited in patents to capture this indicator for more recent years	• Data for 2021 is partial as not all investments events for 2021 captured in Pitchbook at time of the evaluation • Data is primarily presented as a baseline to be monitored going forwards. We note that a small proportion of interviewees suggested that some investments in 2020 /21 may have been influenced by securing ESA contracts	• Data for 2021 is partial as not all investments events for 2021 captured in Pitchbook at time of the evaluation

Indicator	Influencing R&D			GVA (projected)			Employment (projected)		
ToC level	OUTCOME			OUTCOME			OUTCOME		
Data source	Survey of ESA contractors			Survey of ESA contractors / modelling			Survey of ESA contractors / modelling		
Definition	% of respondents reporting an effect of level of internal R&D investment and content of internal R&D activities			Modelling of projected follow-on sales (£) based on data reported in the Survey of ESA contractors			Projected new/ retained employees (FTEs) based on data reported in the Survey of ESA contractors		
Collection frequency	TBD			TBD			TBD		
Time period provided	Baseline	Current	Projected	Baseline	Current	Projected	Baseline	Current	Projected
Caveats / comments				Method presented in Appendix F			Method presented in Appendix F		

A.3 Impact domain: security and protection

Indicator	Access to space	Influencing the global regulatory environment	Resilience of the UK space sector and its supply-chain	Global connectedness of the UK space sector
ToC level	OUTCOME	OUTCOME	OUTCOME	OUTCOME
Data source	Survey of ESA contractors	Survey of ESA contractors	Survey of ESA contractors	Survey of ESA contractors
Definition	% of respondents agreeing that UK investments in ESA (in current CMIN) ensure UK's access to space	% of respondents agreeing that UK investments in ESA (in current CMIN) enhance UKs ability to influence the global regulatory environment	% of respondents agreeing that UK investments in ESA (in current CMIN) enhance the resilience of the UK space sector and its supply-chain	% of respondents agreeing that UK investments in ESA (in current CMIN) enhance the global connectedness of the UK space sector
Collection frequency	TBD	TBD	TBD	TBD
Time period provided	Current	Current	Current	Current
Caveats / comments				

A.4 Impact domain: global influence

Indicator	Political influence in ESA	Political leadership in ESA (1)	Political influence in ESA (2)	UK representation in ESA senior leadership
ToC level	OUTCOME	OUTCOME	OUTCOME	OUTCOME
Data source	Survey of ESA contractors	Survey of ESA contractors	Survey of ESA contractors	Survey of ESA contractors
Definition	% of respondents agreeing that UK has increased its political influence in ESA since Jan 2020	% of respondents agreeing that UK's political leadership in ESA ensures that UK space sector capabilities and needs are reflected in ESA strategy and planning	% of respondents agreeing that UK's political leadership in ESA ensures that the UK's strategic goals for space are reflected in ESA strategy and planning	% of respondents agreeing that the UK is well-represented in ESA senior leadership
Collection frequency	TBD	TBD	TBD	TBD
Time period provided	Current	Current	Current	Current
Caveats / comments				

Appendix B Data Collection Tool: Survey (Industry)

Monitoring & Evaluation of UKSA investments in ESA:
Data Collection Tool

Monitoring & Evaluation of UKSA investments in ESA: Data Collection Tool

1.

Welcome

This data collection tool is intended to capture a range of data and information relevant to the actual and expected benefits generated via ESA contracts.

Suggested approach to competing the data collection tool
The data collection tool is being sent to all organisations that hold ESA contracts and significant sub-contracts. A wide range of data is requested and it may require the compilation of data and information held within your organisation. Therefore, it may be easier to respond if you review this questionnaire in full before completing it.

All responses will be confidential to the study team and the UK Space Agency and only used to monitor the collective impact of public investments.

The UK Space Agency and Technopolis data protection and privacy policies are available here: UK Space Agency privacy policy (https://www.gov.uk/government/publications/uk-space-agency-gdpr-privacy-notice) Technopolis privacy policy (https://www.technopolis-group.com/privacy-policy/).

The data collection process will run from **13 October 2021 to 8 December 2021**.

If you have any questions regarding how to complete the **data collection tool** please contact aaron.vinnik@technopolis-group.com (mailto:aaron.vinnik@technopolis-group.com?subject=UKSA%20investments%20in%20ESA%3A%20Data%20Collection%20Tool)

If you have any questions regarding the monitoring and evaluation study please contact joe.pearsonwood@ukspaceagency.gov.uk (mailto:joe.pearsonwood@ukspaceagency.gov.uk?subject=Monitoring%20%26%20Evaluation%20of%20UKSA's%20investments%20in%20ESA)

Data collection covers the following topics:

About you and your organisation
About your ESA contract(s)
The direct outputs of your ESA contracts

Benefits for your organisation
Benefits beyond your organisation
Visibility and influence
ESA and UK Space Agency processes

Your contribution is very important to the monitoring and evaluation process and we thank you in advance for your inputs.

2.

Please note

Questions are primarily related to your organisation's ESA contract(s) that started since 1 January 2020
Some questions also ask about a period prior to that (2018-2019) to enable us to determine changes between investment periods. If you do not have data to report for the earlier period, please leave these blank

All questions relate to a specific ESA programme area (e.g. Science, Earth Observation, Telecoms, GSTP, etc), unless otherwise specified. Where your organisation has contracts under more than one ESA programme, you or a colleague will have received a separate data collection tool for each programme.

If any questions are not relevant to your organisation please leave the response boxes blank

Where actual data are not available (e.g. detailed breakdowns), please provide approximations

Please confirm for which ESA programme you are providing data for: *

- [ ] Space Science
- [ ] Human and Robotic Exploration
- [ ] Telecommunication and Integrated Applications (also known as ARTES: Advanced Research in Telecommunication Systems)
- [ ] Earth Observation
- [ ] NAVISP - Navigation Innovation and Support
- [ ] GSTP - General Support Technology Programme
- [ ] CSTS - Commercial Space Transportation Services and Support
- [ ] Space Safety and Security
- [ ] Other (please specify):

3.

About you and your organisation

What is your organisation's name? *

Please tell us about yourself

Name:

Position:

Email:

1. Does your organisation have UK-based operations?

Select one

- [ ] Yes
- [ ] No

2. Is your organisation...

Select one

- [ ] UK-owned
- [ ] Mixed ownership (UK and foreign)
- [ ] Foreign-owned

3. How would you classify your organisation?

Select one

- [ ] Micro enterprise (<10 employees)
- [ ] Small or Medium-sized Enterprise, SME (11-250 employees)
- [ ] Large enterprise (>250 employees)
- [ ] Higher Education Institution
- [ ] Other Research / Non-commercial organisation (please specify):

If you require assistance, please contact: Aaron Vinnick aaron.vinnik@technopolis-group.com (mailto:aaron.vinnik@technopolis-group.com?subject=Request%20for%20assistance%20with%20UK%20ESA%20survey)

4.

About your ESA contract(s)

4. Did your company secure any ESA contracts under the programme before 2020?

- [ ] Yes
- [ ] No

With regards to your ESA contract(s) under the programme....

Please populate all that apply

	In period 2018 - 2019 (2 full calendar years)	In period 2020 - 2021 (2 full calendar years)
How many contracts have you secured (#)		
What is their total value to your organisation (£m)		

Additional comments:

6. Thinking only about your ESA contracts since 1st January 2020, please tell us about stage of development (as a TRL*) of the key technologies (components, systems, etc) that you are developing:

*** Technology Readiness Levels (TRLs) estimate the maturity of technologies on a scale (1 to 9). More information on TRLs is available here (https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Shaping_the_Future/Technology_Readiness_Levels_TRL).**

Please populate as many rows as you need

	Technology (please insert technology name)	TRL at start of ESA contract	TRL now	TRL expected at end of ESA contract
1.				
2.				
3.				
4.				
5.				
6.				
7.				

Please provide brief additional details of key technologies progressed:

7. Do your ESA contracts involve collaborations with:

Please select all that apply

	In period 2018 - 2019 (2 full calendar years)	In period 2020 - 2021 (2 full calendar years)
Businesses in the UK	☐	☐
Businesses in other ESA Member States	☐	☐
Businesses internationally (i.e. other than ESA Member States)	☐	☐
Academics or public research institutes in the UK	☐	☐
Academics or public research institutes in other ESA member states	☐	☐
Academics or public research institutes internationally (i.e. other than ESA Member States)	☐	☐

Please provide brief additional details of collaborations:

If you require assistance, please contact: Aaron Vinnick aaron.vinnik@technopolis-group.com (mailto:aaron.vinnik@technopolis-group.com?subject=Request%20for%20assistance%20with%20UK%20ESA%20survey)

5.

The outputs of your ESA contract(s)

8. How many of the following have been generated as a direct result of your ESA contract(s):

Please populate all that apply

	In period 2018 - 2019 (2 full calendar years)	In period 2020 - 2021 (2 full calendar years)
Number of publications authored /co-authored by your organisation (#) *N.B. We do not require information on papers that arise from use of ESA space assets as these are captured via other means*		
Number of patents granted (#)		
Value of license income from patents arising from ESA contracts (£m)		

Please provide patent numbers and DOIs for publications and any additional information regarding licenses:

9. How many new products / services have been commercialised as a result of your ESA contract(s)?

Please populate all that apply

	In period 2018 - 2019 (2 full calendar years)	In period 2020 - 2021 (2 full calendar years)	Expected from 2022 onwards
Number of products / services commercialised (#)			

Please provide additional information on the products / services commercialised (e.g. description of the products/services, the applications they are being used or will be used for, and who the customers / expected customers are):

10. Have your ESA contracts led to new or improved...

Please select all that apply

	In period 2018 - 2019 (2 full calendar years)	In period 2020 - 2021 (2 full calendar years)
Employee skills / knowledge	☐	☐

Please provide additional information or examples of the skills / knowledge acquired or improved::

11. Thinking only about your ESA contracts since 1 January 2020, are any of the key technologies (components, system, etc) generated providing or contributing to operational space infrastructures?

Please select all that apply

Have already contributed to operational space infrastructure	☐
Expected to contribute to operational space infrastructure	☐

If any of your key technologies (components, system, etc) generated from your recent ESA contracts have contributed (or are expected to contribute) to operational space infrastructures then please provide details below:

Already contributed to operational space infrastructures	
Expected to contribute to operational space infrastructures (please include information in expected timescales to operational space infrastructures)	

If you require assistance, please contact: Aaron Vinnick aaron.vinnik@technopolis-group.com (mailto:aaron.vinnik@technopolis-group.com?subject=Request%20for%20assistance%20with%20UK%20ESA%20survey)

6.

Continuing benefits of ESA contract(s) to your organisation

Follow-on sales resulting from capabilities developed under ESA contracts

12. Thinking of the outputs of your ESA contracts (new and improved capabilities, products / services commercialised), what follow-on sales do they support?

Please populate all that apply

	In period 2018 - 2019 (2 full calendar years)	In period 2020 - 2021 (2 full calendar years)	Expected from 2022 onwards
Income generated by these capabilities / products / services (£m)			
Proportion of this income achieved through **exports** (%)			
If these capabilities / products / services enabled you to enter new markets (new overseas markets, new sectors) what is the **number of new markets accessed**			

Please provide additional comments (e.g. examples of exports achieved, new geographical markets or sectors entered, expected timings for future outputs):

13. How many full-time equivalent (FTE) employees were created and/or retained by your company as a result of....

Please populate all that apply

	In period 2018 - 2019 (2 full calendar years)	In period 2020 - 2021 (2 full calendar years)	Expected from 2022 onwards
Your ESA contract income (FTEs)			
Income generated by the new capabilities / products / services resulting from ESA contracts (FTEs)			

14. Based on the employee figures provided above, for years 2020-2021 please estimate the UK regional and devolved administration distribution of FTEs:

	Distribution (%)
Scotland	
Wales	
N. Ireland	
East of England	

	Distribution (%)
East Midlands	
London	
North East	
North West	
South East	
South West	
West Midlands	
Yorkshire and the Humber	

Please provide additional comments related to employment changes or the distribution of employment:

New strategic partnerships

15. Thinking only about your ESA contracts since 1 January 2020, have any of these contract(s) led to any new significant strategic international partnerships*?

*** These may include new commercial relationships with space agencies, new supplier-contractor relationships that are viewed as consequential for your organisation, new important partnerships with research organisations, etc.**

Please populate all that apply

	In period 2020 - 2021 (2 full calendar years)	Expected from 2022 onwards
Number of new significant strategic international partnerships in Europe (non-UK)		
Number of new significant strategic international partnerships outside Europe		

Please provide brief details of new significant partnerships created or supported as a result of your ESA contracts:

16. As a result of your ESA contract(s) since 1 January 2020, to what extent has your organisation experienced...

Please select only one response per row

	To a significant extent	To a small extent	No effect Negative effect
Increased reputation, credibility, visibility within international space markets	☐	☐	☐
Increased competitiveness within international space markets	☐	☐	☐

	To a significant extent	To a small extent	No effect Negative effect
Reduced barriers to entry to international space markets	☐	☐	☐
Reduced transaction costs within the international space market (e.g. due diligence, negotiations, contract enforcement)	☐	☐	☐
Increased attention from the media and/or public	☐	☐	☐

Please provide additional comments on how ESA contracts have affected these factors:

If you require assistance, please contact: Aaron Vinnick aaron.vinnik@technopolis-group.com (mailto:aaron.vinnik@technopolis-group.com?subject=Request%20for%20assistance%20with%20UK%20ESA%20survey)

7.

Continuing benefits of ESA contract(s) beyond your organisation

Spin-outs

17. Have any spin-out businesses (i.e. a new company created to commercialise a particular innovation or technology) been created as a result of your ESA contracts? If so, what is the...

Please populate all that apply

	In period 2018 - 2019 (2 full calendar years)	In period 2020 - 2021 (2 full calendar years)	Expected from 2022 onwards
Number of new spin-outs formed (#)			
Number of employees working at these spin-outs (#)			
Investment raised by spin-outs (£m)			
Annual turnover of these spin-outs (£m) (if known)			

Please provide brief details of spin-outs created (e.g. name, location, date spun-out):

Other benefits

18. In the last 5 years, has your organisation...

Please select all that apply

- ☐ Moved to the UK from abroad
- ☐ Established a UK subsidiary
- ☐ Expanded its UK operations
- ☐ Received investment from UK sources (not including that from parent company or owner)
- ☐ Received investment from non-UK sources (not including that from parent company or owner)

If 'yes' to any of the above, please provide additional details as to (i) the timing, scale and financial value of these activities, expansions and/or investments, and (ii) any role or influence played by the UK's investment in ESA programmes:

19. Have your ESA contracts influenced your internal R&D activities?

Please select only one response per row

	To a significant extent	To a small extent	No effect	Negative effect
Level of internal investment in R&D	☐	☐	☐	☐
Content of R&D activities	☐	☐	☐	☐

Please provide details of any increased R&D investment and/or changes to content of R&D activities:

20. Has your organisation experienced any other benefits, not covered by your response so far, as a result of your ESA contracts? If so, please provide some brief details:

21. Which of the following statements most accurately describes the extent to which the benefits reported above are linked to your ESA contracts?

Please select only one response *

- ☐ These benefits could not have occurred without the ESA contract(s)
- ☐ Only a small proportion of these benefits would have occurred without the ESA contract(s)
- ☐ A notable proportion of these benefits could have occurred without the ESA contract(s)
- ☐ Most of the benefits could have occurred without the ESA contract(s)
- ☐ All of the benefits could have occurred without the ESA contract(s)
- ☐ Not applicable – no changes seen through ESA contract(s)

Usage benefits

22. Thinking about your recent ESA contract(s) (i.e. those that started since 1 January 2020), do you expect them to lead applications and benefits in...

Please select only one response per row. See below for examples of relevant benefits.

Environmental quality & protection	e.g. pollution reduction, resource efficiency, ecosystem protection, and climate understanding
Security – of space assets	e.g. improved cyber security resilience and protection of in-space assets
Security – of assets on Earth	e.g. protection of critical national infrastructure (energy systems, emergency systems, communications, defence and security forces, police, financial systems)
Productivity	e.g. time & cost savings to consumers, new products and services developed by businesses and society from programme activity, improved labour productivity and other efficiency benefits
Effective public policy design and public service efficiency	e.g. the ability to provide faster, better or cheaper public services as a result of new products and services developed through programme funding
Health, welfare and utility	e.g. reduction in illness/injury/fatalities or improvement in welfare

	Significant benefits	Minimal benefits	No benefits
Environmental quality and protection	☐	☐	☐
Security – of space assets	☐	☐	☐
Security – of assets on Earth	☐	☐	☐
Productivity	☐	☐	☐
Effective public policy design and public service efficiency	☐	☐	☐
Health, welfare and utility	☐	☐	☐

Please provide additional comments on any benefits expected (e.g. your thoughts on the nature and scale of the benefits):

Timing of benefits

23. Thinking about the benefits generated by UK investment in ESA, what is your view on the typical timescales to the start of benefits, and the duration of benefits?

Please complete each cell

	Time between start of ESA contract and start of benefit (in years)	Duration of benefit (in years)
Operational space capabilities		
Patents granted		
Income from licensed patents		
Papers published		
New products/ services commercialised or new capabilities available on the market		
Follow-on sales based on new products/ services/ capabilities		
New downstream applications available for use (i.e. those reported in Q17)		

lease provide additional comments or information on timescales and duration of benefits:

If you require assistance, please contact: Aaron Vinnick aaron.vinnik@technopolis-group.com (mailto:aaron.vinnik@technopolis-group.com?subject=Request%20for%20assistance%20with%20UK%20ESA%20survey)

8.

Visibility and influence

24. Please list:

Any executive, advisory and/or observer roles members of your organisation holds within ESA	
Any executive, advisory and/or observer roles members of your organisation holds within the wider international space community	
Any (non-ESA) international standards-setting body members of your organisation sits on that influence the planning and operations of space activities and applications	

25. To what extent do you agree with the following statements regarding the UK's investments in ESA?

Please select only one response per row.
NB. We are interested in the current ESA Ministerial funding round (i.e. 1 January 2020 - present).

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
The UK is well-represented within ESA senior leadership	☐	☐	☐	☐	☐
UK's political leadership in ESA ensures that the UK's **strategic goals for space** are reflected in ESA strategy and planning	☐	☐	☐	☐	☐
UK's political leadership in ESA ensures that UK **space sector's capabilities and needs** (in industry and academia) are reflected in ESA strategy and planning	☐	☐	☐	☐	☐
The UK has **increased its political influence** within ESA since January 2020	☐	☐	☐	☐	☐
UK investment in ESA enhances the **global connectedness** of the UK space sector	☐	☐	☐	☐	☐
UK investment in ESA enhances the **resilience** of the UK space sector and its supply-chain	☐	☐	☐	☐	☐

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
UK investment in ESA enhances **UK's ability to influence** the global regulatory environment regarding space	☐	☐	☐	☐	☐
UK investment in ESA **ensures UK's access to space**	☐	☐	☐	☐	☐

Please provide additional comments on your views (e.g. can you provide a rationale for these ratings or examples to demonstrate them):

If you have any further comments about the nature and impact of your ESA contract(s), please provide them here:

If you require assistance, please contact: Aaron Vinnick aaron.vinnik@technopolis-group.com (mailto:aaron.vinnik@technopolis-group.com?subject=Request%20for%20assistance%20with%20UK%20ESA%20survey)

9.

ESA and UK Space Agency processes

We are interested in understanding your overall experience of applying for and delivering an ESA contract. This includes processes used by ESA and the UK Space Agency.

26. Firstly, which type of contracting method did you use:

Please select all that apply

	In period 2020-2021 (2 full calendar years)
An open competitive call published by ESA	☐
A restricted competitive call led by ESA	☐
An open competitive call published by UK Space Agency	☐
A restricted competitive call led by UK Space Agency	☐
Direct negotiation with ESA	☐

Other (please specify):

27. Thinking about all stages of the ESA application process (e.g. expression of interest, full application, contract negotiation, etc), how satisfied or dissatisfied were you with...

Please answer all questions

	Not applicable	Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
The information and support provided during the application process	☐	☐	☐	☐	☐	☐
The amount of time given to applicants to submit an expression of interest (EoI)	☐	☐	☐	☐	☐	☐
The amount of time given to applicants to submit a proposal	☐	☐	☐	☐	☐	☐
The time taken from submission of proposal to ESA decision	☐	☐	☐	☐	☐	☐
The clarity of the feedback on the decision(s) made about your application(s)	☐	☐	☐	☐	☐	☐
The effectiveness of the contract negotiation process	☐	☐	☐	☐	☐	☐

Thinking about how the application process for ESA funding might be improved, what one element of the ESA application process would you change, and why?

What one element of the ESA application process would you NOT change, and why?

28. Thinking about delivering the contract(s), how satisfied or dissatisfied are / were you with the following ESA processes:

Please answer all questions

	Not applicable	Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied	
The administrative support provided during the contract	☐	☐	☐	☐	☐	☐	☐
The technical support (advice) provided during the contract	☐	☐	☐	☐	☐	☐	☐
The technical support (access to ESA technical facilities) provided during the contract	☐	☐	☐	☐	☐	☐	☐
The frequency of in-contract reporting	☐	☐	☐	☐	☐	☐	☐
The content of in-contract reporting	☐	☐	☐	☐	☐	☐	☐
The responsiveness to requests and queries for information, advice, support	☐	☐	☐	☐	☐	☐	☐
Support to make links with new contacts within the space sector	☐	☐	☐	☐	☐	☐	☐
Support to identify potential routes to further funding (after a contract)	☐	☐	☐	☐	☐	☐	☐

Thinking about how the ESA processes to support contract delivery might be improved, what one ESA process would you change, and why?

What one ESA process would you NOT change, and why?

29. Thinking about all stages of the UK Space Agency part of the application process (e.g. expression of interest, full application, letter of support), how satisfied or dissatisfied were you with:

Please answer all questions

	Not applicable	Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
The information and support provided during the application process	☐	☐	☐	☐	☐	☐
The amount of time given to applicants to submit an expression of interest (EoI)	☐	☐	☐	☐	☐	☐
The amount of time given to applicants to submit a proposal	☐	☐	☐	☐	☐	☐
The time taken from submission of proposal to UK Space Agency decision	☐	☐	☐	☐	☐	☐
The clarity of the feedback on the decision(s) made about your application(s)	☐	☐	☐	☐	☐	☐

Thinking about how the application process for ESA funding might be improved, what one element of the UK Space Agency application process would you change, and why?

What one element of the UK Space Agency part of the application process would you NOT change, and why?

30. Thinking about delivering the contract(s), how satisfied or dissatisfied are / were you with the following UK Space Agency processes:

Please answer all questions

	Not applicable	Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
The administrative support provided during the contract	☐	☐	☐	☐	☐	☐
The technical support (advice) provided during the contract	☐	☐	☐	☐	☐	☐
The responsiveness to requests and queries for information, advice, support	☐	☐	☐	☐	☐	☐
Support to make links with new contacts within the space sector	☐	☐	☐	☐	☐	☐
Support to identify potential routes to further funding (after a contract)	☐	☐	☐	☐	☐	☐

Thinking about how the UK Space Agency processes to support contract delivery might be improved, what one UK Space Agency process would you change, and why?

What one UK Space Agency process would you NOT change, and why?

If you require assistance, please contact: Aaron Vinnick aaron.vinnik@technopolis-group.com (mailto:aaron.vinnik@technopolis-group.com?subject=Request%20for%20assistance%20with%20UK%20ESA%20survey)

Academic / Research Institute Data Collection

Appendix C Data Collection Tool: Survey (academic)

Monitoring & Evaluation of UK Space Agency's investments in ESA:
Academic / Research Institute Data Collection

Monitoring & Evaluation of UK Space Agency's investments in ESA – Academic / Research Institute Data Collection

1. Introduction

This data collection tool is intended to capture a range of data and information relevant to the actual and expected benefits generated via ESA contracts.

Suggested approach to competing the data collection tool
The data collection tool is being sent to all organisations (businesses and research groups) that hold ESA contracts and significant sub-contracts. A wide range of data is requested and it may require the compilation of data and information held within your organisation. Therefore, it may be easier to respond if you review this questionnaire in full before completing it.

All responses will be confidential to the study team and the UK Space Agency and only used to monitor the collective impact of public investments. The UK Space Agency and Technopolis data protection and privacy policies are available here: UK Space Agency privacy policy (https://www.gov.uk/government/publications/uk-space-agency-gdpr-privacy-notice) Technopolis privacy policy (https://www.technopolis-group.com/privacy-policy/).

The data collection process will run from **25 October 2021 to 5 November 2021**.

If you have any questions regarding how to complete the **data collection tool** please contact aaron.vinnik@technopolis-group.com (mailto:aaron.vinnik@technopolis-group.com).

If you have any questions regarding the **monitoring and evaluation study** please contact joe.pearsonwood@ukspaceagency.gov.uk (mailto:joe.pearsonwood@ukspaceagency.gov.uk).

Data collection covers the following topics:

About you and your research group
About your ESA contract(s)
The direct outputs of your ESA contracts
Benefits for your research group
Benefits beyond your research group
Visibility and influence
ESA and UK Space Agency processes

Your contribution is very important to the monitoring and evaluation process and we thank you in advance for your inputs.

2. Monitoring & Evaluation of UK Space Agency's investments in ESA – Academic / Research Institute Data Collection

Please note:

Questions are primarily related to your organisation's ESA contract(s) that started since 1 January 2020
Some questions also ask about a period prior to that (2018-2019) to enable us to determine changes between investment periods. If you do not have data to report for the earlier period, please leave these blank

All questions relate to a specific ESA programme area (e.g. Science, Earth Observation, Telecoms, GSTP, etc), unless otherwise specified. Where your organisation has contracts under more than one ESA programme, you or a colleague will have received a separate data collection tool for each programme.

If any questions are not relevant to your organisation please leave the response boxes blank
Where actual data are not available (e.g. detailed breakdowns), please provide approximations

Please confirm you are providing data for ESA Programme: *

- [ ] Space Science
- [ ] Human and Robotic Exploration
- [ ] Telecommunication and Integrated Applications (also known as ARTES: Advanced Research in Telecommunication Systems)
- [ ] Earth Observation
- [ ] NAVISP - Navigation Innovation and Support Programme
- [ ] GSTP - General Support Technology Programme
- [ ] CSTS - Commercial Space Transportation Services and Support Programme
- [ ] Space Safety and Security Programme
- [ ] None / Other (please specify):

3.

About you and your research group

Please tell us about yourself *

Name:

Position:

Email:

Research group name: *

Institution name (e.g. University of xxx): *

1. Does your research group have UK-based operations?
Select one

- ☐ Yes
- ☐ No

2. Is your research group
Select one

- ☐ Within a Higher Education institution
- ☐ Within a research institute, public laboratory, RTO
- ☐ Other

3. How many people work in.....
(in FTEs - full-time equivalent employees)
Provide a number of FTEs

	Number of FTEs
In your research group	
In the area of work relevant to this ESA programme	

If you require assistance, please contact: Aaron Vinnik aaron.vinnik@technopolis-group.com (http://aaron.vinnik@technopolis-group.com)

4.

About your ESA contract(s)

4. Did your research group secure any ESA contracts under the [X] programme before 2020?

- [ ] Yes
- [ ] No

5. With regards to your ESA contract(s) under the [X] programme
Please populate all that apply

	In period 2018 – 2019 (2 full calendar years)	In period 2020 - 2021 (2 full calendar years)
How many contracts have you secured (#)		
What is their total value to your research group (£m)		

Additional comments:

6. Thinking only about your ESA contracts since 1st January, please tell us about stage of development (as a TRL*) of the key technologies (components, systems, etc) that you are developing:

*** Technology Readiness Levels (TRLs) estimate the maturity of technologies on a scale (1 to 9). More information on TRLs is available here (https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Shaping_the_Future/Technology_Readiness_Levels_TRL)**
Please populate as many rows as you need

	Technology (please insert technology name)	TRL at the start of the current ESA contract	TRL now	TRL expected at the end of the current ESA contract
1.				
2.				
3.				
4.				
5.				
6.				
7.				

Please provide brief additional details of key technologies progressed

7. Do your ESA contracts involve collaborations with:
Please select all that apply

	In period 2018-2019 (2 full calendar years)	in period 2020-2021 (2 full calendar years)
Businesses in the UK	☐	☐
Businesses in other ESA Member States	☐	☐
Businesses internationally (i.e. other than ESA Member States)	☐	☐
Academics or public research institutes in the UK	☐	☐
Academics or public research institutes in other ESA Member States	☐	☐
Academics or public research institutes internationally (i.e. other than ESA Member States)	☐	☐

Please provide brief additional details of collaborations

If you require assistance, please contact: Aaron Vinnik aaron.vinnik@technopolis-group.com (http://aaron.vinnik@technopolis-group.com)

5.

The outputs of your ESA contract(s)

8. Thinking of the outputs of your ESA contracts: how many of the following have been generated as a direct result of your ESA contract(s):
Please populate all that apply

	In period 2018-2019 (2 full calendar years)	In period 2020-2021 (2 full calendar years)
Number of publications authored /co-authored by your research group (#) **(N.B. We are seeking publications from your ESA contracts directly. We do not require information on papers that arise from use of ESA space assets as these are captured via other means)**		
Number of patents granted (#)		
Value of license income from patents arising from ESA contracts (£m)		
Number of MSc and PhD completed		

Please provide patents numbers and DOIs for publications and additional information regarding licences

9. How many new products / services have been commercialised as a result of your ESA contract(s)?
Please populate all that apply

	In period 2018-2019 (2 full calendar years)	in period 2020-2021 (2 full calendar years)	Expected from 2022 onwards
Number of products / services commercialised (#)			

Please provide additional information on the products / services commercialised (e.g. description of the products/services, the applications they are /or will be used for and the customers/expected customers are)

If you require assistance, please contact: Aaron Vinnik aaron.vinnik@technopolis-group.com (http://aaron.vinnik@technopolis-group.com)

10. Have your ESA contracts led to new or improved...
Please select all that apply

	In period 2018-2019 (2 full calendar years)	In period 2020-2021 (2 full calendar years)
Researcher skills / knowledge	☐	☐

Please provide additional information or examples of the skills / knowledge acquired or improved

11. Thinking only about your ESA contracts since 1st January 2020, are any of the key technologies (components, system, etc) generated providing or contributing to operational space infrastructures?
Please select all that apply

Have already contributed to operational space infrastructure	☐
Expect to contribute to operational space infrastructure	☐

If any of your key technologies (components, system, etc) generated from your recent ESA contracts have contributed (or are expected to contribute) to operational space infrastructures then please provide details below:

Already contributed to operational space infrastructures	
Expected to contribute to operational space infrastructures (please include information in expected timescales to operational space infrastructures)	

If you require assistance, please contact: Aaron Vinnik aaron.vinnik@technopolis-group.com (http://aaron.vinnik@technopolis-group.com)

7.

Continuing benefits of ESA contract(s) to your research group

Follow-on grants and contracts resulting from capabilities developed under ESA contracts

12. Thinking of the outputs of your ESA contracts (new and improved capabilities, products /services commercialised); what follow-on grants or contracts do they support?
Please populate all that apply

	In period 2018 – 2019 (2 full calendar years)	In period 2020 - 2021 (2 full calendar years)	Expected from 2022 onwards
Value of income from grants generated by these capabilities /products / services (£m)			
Value of income from contracts generated by these capabilities /products / services (£m)			
Proportion of this income achieved through **exports** (%) i.e. contracts from overseas			
If these capabilities /products / services enabled you to enter new markets (new overseas markets, new sectors) what is the **number of new markets accessed**			

Please provide additional comments (e.g. significant new grants or contracts achieved, examples of exports achieved, new geographical markets or sectors entered, expected timings for future outputs)

Employment

13. How many full-time equivalent researcher positions (including PhDs) were created and/or retained by your research group in the UK as a result of...
Please populate all that apply

	In period 2018 – 2019 (2 full calendar years)	In period 2020 - 2021 (2 full calendar years)	Expected from 2022 onwards
Your ESA contract income (FTEs)			
Income generated by the new capabilities/products/services resulting from ESA contracts (FTEs)			

14. Based on the employee figures provided above for years 2020-2021, could you please estimate the regional distribution of FTEs?

	Distribution (%)
Scotland	
Wales	
N. Ireland	
East of England	
East Midlands	
London	
North East	
North West	
South East	
South West	

	Distribution (%)
West Midlands	
Yorkshire and the Humber	

Please provide additional comments related to employment changes or the distribution of employment

New strategic partnerships

15. Thinking only about your ESA contracts since 1st January 2020, have any of these contract(s) led to any new significant strategic international partnerships*?
Please populate all that apply

	In period 2020 - 2021 (2 full calendar years)	Expected from 2022 onwards
Number of new significant strategic international partnerships in Europe (non-UK)		
Number of new significant strategic international partnerships outside Europe		

Please provide brief details of new significant partnerships created or supported as a result of your ESA contracts. *These may include new commercial relationships with space agencies, new supplier-contractor relationships that are viewed as consequential for your research group, new important partnerships with research organisations

16. As a result of your ESA contract(s) since 1st January 2020, to what extent has your research group experienced...
Please select only one response per row

	To a significant extent	To a small extent	No effect	Negative effect
Increased reputation, credibility, visibility within international space markets	☐	☐	☐	☐
Increased competitiveness within international space markets	☐	☐	☐	☐
Reduced barriers to entry to international space markets	☐	☐	☐	☐
Reduced transaction costs within the international space market (e.g. due diligence, negotiations, contract enforcement)	☐	☐	☐	☐
Increased attention from the media and/or public	☐	☐	☐	☐

Please provide additional comments on how ESA contracts have affected these factors

If you require assistance, please contact: Aaron Vinnik aaron.vinnik@technopolis-group.com (http://aaron.vinnik@technopolis-group.com)

8.

Continuing benefits of ESA contract(s) beyond your research group

Spin-outs

17. Have any spin-out businesses (i.e. a new company created to commercialise a particular innovation or technology) been created as a result of your ESA contracts? If so, what is the...
Please populate all that apply

	In period 2018 – 2019 (2 full years)	In period 2020 – 2021 (2 full years)	Expected from 2022 onwards
Number of new spin-outs formed (#)			
Number of employees working at these spin-outs (#)			
Investment raised by spin-outs (£m)			
Annual turnover of these spin-outs (£m) (if known)			

Please provide brief details of spin-outs created (e.g. name, location, date spun-out)

Other benefits

18. Have your ESA contracts influenced your R&D activities
Please select only one response per row

	To a significant extent	To a small extent	No effect	Negative effect
Content of R&D activities	☐	☐	☐	☐

Please provide details of any changes to content of R&D activities

If you require assistance, please contact: Aaron Vinnik aaron.vinnik@technopolis-group.com (http://aaron.vinnik@technopolis-group.com)

19. Has your research group experienced any other benefits, not covered by your response so far, as a result of your ESA contracts? If so, please provide some brief details.

20. Which of the following statements most accurately describes the extent to which the benefits reported above are linked to your ESA contracts?
Please select only one response *

- ☐ These benefits could not have occurred without the ESA contract(s)
- ☐ Only a small proportion of these benefits would have occurred without the ESA contract(s)
- ☐ A notable proportion of these benefits could have occurred without the ESA contract(s)
- ☐ Most of the benefits could have occurred without the ESA contract(s)
- ☐ All of the benefits could have occurred without the ESA contract(s)
- ☐ Not applicable – no changes seen through ESA contract(s)

Usage benefits

21. Thinking about your recent ESA contract(s) (i.e. those that started since 1st January 2020), do you expect them to lead applications and benefits in...
Please select only one response per row

Environmental quality and protection	e.g. pollution reduction, resource efficiency, ecosystem protection, and climate understanding
Security – of space assets	e.g. improved cyber security resilience and protection of in-space assets
Security – of assets on Earth	e.g. protection of critical national infrastructure (energy systems, emergency systems, communications, defence and security forces, police, financial systems etc)
Productivity	e.g. time & cost savings to consumers, new products and services developed by businesses and society from programme activity, improved labour productivity and other efficiency benefits
Effective public policy design and public service efficiency	e.g. the ability to provide faster, better or cheaper public services as a result of new products and services developed through programme funding
Health, welfare and utility	e.g. reduction in illness/injury/fatalities or improvement in welfare

	Significant benefits	Minimal benefits	No benefits
Environmental quality and protection	☐	☐	☐
Security – of space assets	☐	☐	☐
Security – of assets on Earth	☐	☐	☐
Productivity	☐	☐	☐
Effective public policy design and public service efficiency	☐	☐	☐
Health, welfare and utility	☐	☐	☐

Please provide additional comments on any benefits expected (e.g. your thoughts on the nature and scale of the benefits)

Timing of benefits

22. Thinking about the benefits generated by UK investment in ESA, what is your view on the typical timescales to the start of benefits and the duration of benefits?
Please complete each cell

	Time between start of ESA contract and start of benefit (in years)	Duration of benefit (in years)
Operational space capabilities		
Patents granted		
Income from licensed patents		
Papers published		
New products/ services commercialised or new capabilities available on the market		

	Time between start of ESA contract and start of benefit (in years)	Duration of benefit (in years)
New products/ services commercialised or new capabilities available for scientific activities		
Follow-on income (grants/ contracts) based on new products/ services/ capabilities		
New downstream applications available for use (i.e. those reported in question above)		

Please provide additional comments or information on timescales and duration of benefits

If you require assistance, please contact: Aaron Vinnik aaron.vinnik@technopolis-group.com (http://aaron.vinnik@technopolis-group.com)

10.

Visibility and influence

23. Please list:

Any executive, advisory and/or observer roles members of your research group holds within ESA	
Any executive, advisory and/or observer roles members of your research group holds within the wider international space community	
Any (non-ESA) international standards-setting body members of your research group sits on that influence the planning and operations of space activities and applications	

24. To what extent do you agree with the following statements regarding the UK's investments in ESA?
Please select only one response per row

NB. We are interested in the current ESA Ministerial funding round (i.e. 1 January 2020 - present).

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
The UK is well-represented within ESA senior leadership	☐	☐	☐	☐	☐
UK's political leadership in ESA ensures that the UK's **strategic goals for space** are reflected in ESA strategy and planning	☐	☐	☐	☐	☐
UK's political leadership in ESA ensures that UK **space sector's capabilities and needs** (in industry and academia) are reflected in ESA strategy and planning	☐	☐	☐	☐	☐
The UK has **increased its political influence** within ESA since January 2020	☐	☐	☐	☐	☐
UK investment in ESA enhances the global connectedness of the UK space sector	☐	☐	☐	☐	☐
UK investment in ESA enhances the resilience of the UK space sector and its supply-chain	☐	☐	☐	☐	☐
UK investment in ESA enhances UK's ability to influence the global regulatory environment regarding space	☐	☐	☐	☐	☐
UK investment in ESA assures UK's access to space	☐	☐	☐	☐	☐

Pease provide additional comments on your views (e.g. can you provide a rationale for these ratings or examples to demonstrate them)

If you have any further comments about the nature and impact of your ESA contract(s), please provide them here:

If you require assistance, please contact: Aaron Vinnik aaron.vinnik@technopolis-group.com (http://aaron.vinnik@technopolis-group.com)

11.

ESA and UK Space Agency processes

We are interested to understand your overall experience of applying for and delivering an ESA contract. This includes processes used by ESA and the UK Space Agency.

25. Firstly, which type of contracting method did you use:
Please select all that apply

	In period 2020-2021 (2 full calendar years)
An open competitive call published by the ESA	☐
A restricted competitive call led by ESA	☐
An open competitive call published by UK Space Agency	☐
A restricted competitive call led by UK Space Agency	☐
Direct negotiation with ESA	☐

Other

26. Thinking about all stages of the ESA application process (e.g. expression of interest, full application, contract negotiation, etc), how satisfied or dissatisfied were you with...
Please answer all questions

	Not applicable	Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
The information and support provided during the application process	☐	☐	☐	☐	☐	☐
The amount of time given to applicants to submit and expression of interest (EoI)	☐	☐	☐	☐	☐	☐
The amount of time given to applicants to submit a proposal	☐	☐	☐	☐	☐	☐
The time taken from submission of proposal to ESA decision	☐	☐	☐	☐	☐	☐
The clarity of the feedback on the decision(s) made about your application(s)	☐	☐	☐	☐	☐	☐
The effectiveness of the contract negotiation process	☐	☐	☐	☐	☐	☐

Thinking about how the application process for ESA funding might be improved, what one element of the ESA application process would you change, and why?

What one element of the ESA application process would you NOT change, and why?

27. Thinking about delivering the contract(s), how satisfied or dissatisfied were you with the following ESA processes
Please answer all questions

	Not applicable	Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
The administrative support provided during the contract	☐	☐	☐	☐	☐	☐
The technical support (advice) provided during the contract	☐	☐	☐	☐	☐	☐

	Not applicable	Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
The technical support (access to ESA technical facilities) provided during the contract	☐	☐	☐	☐	☐	☐
The frequency of in-contract reporting	☐	☐	☐	☐	☐	☐
The content of in-contract reporting	☐	☐	☐	☐	☐	☐
The responsiveness to requests and queries for information, advice, support	☐	☐	☐	☐	☐	☐
Support to make links with new contacts within the space sector	☐	☐	☐	☐	☐	☐
Support to identify potential routes to further funding (after a contract)	☐	☐	☐	☐	☐	☐

Thinking about how the ESA processes to support contract delivery might be improved, what one ESA process would you change, and why?

Thinking about how the ESA processes to support contract delivery might be improved, what one ESA process would you change, and why?

What one ESA process would you NOT change, and why?

28. Thinking about all stages of the UK Space Agency part of application process, where relevant (e.g. expression of interest, full application, letter of support, etc), how satisfied or dissatisfied were you with...
Please answer all questions

	Not applicable	Very dissatisfied	Dissatisfied	Neither satisfied or dissatisfied	Satisfied	Very satisfied
The information and support provided during the application process	☐	☐	☐	☐	☐	☐
The amount of time given to applicants to submit an expression of interest (EoI)	☐	☐	☐	☐	☐	☐
The amount of time given to applicants to submit a proposal	☐	☐	☐	☐	☐	☐
The time taken from submission of proposal to UK decision	☐	☐	☐	☐	☐	☐
The clarity of the feedback on the decision(s) made about your application(s)	☐	☐	☐	☐	☐	☐

Thinking about how the application process for ESA funding might be improved, what one element of the UK Space Agency part of the application process would you change, and why?

What one element of the UK Space Agency part of the application process would you NOT change, and why?

29. Thinking about delivering the contract(s), how satisfied or dissatisfied were you with UK Space Agency processes
Please answer all questions

	Not applicable	Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
The administrative support provided during the contract	☐	☐	☐	☐	☐	☐
The technical support (advice) provided during the contract	☐	☐	☐	☐	☐	☐
The responsiveness to requests and queries for information, advice, support	☐	☐	☐	☐	☐	☐
Support to make links with new contacts within the space sector	☐	☐	☐	☐	☐	☐
Support to identify potential routes to further funding (after a contract)	☐	☐	☐	☐	☐	☐

Thinking about how the UK Space Agency processes to support contract delivery might be improved, what one UK Space Agency process would you change, and why?

What one UK Space Agency process would you NOT change, and why?

If you require assistance, please contact: Aaron Vinnik aaron.vinnik@technopolis-group.com (http://aaron.vinnik@technopolis-group.com)

Appendix D Interviewees

Name	Institution
Ryan Mcglen	Aavid Thermacore
Alex Clarke	ABSL Space Products
Steve Wells	Adaptix Ltd
Marie Claire Perkinson	Airbus Defence and Space Limited
Ralph Cordey	Airbus Defence and Space Limited
Matthew Stuttard	Airbus Defence and Space Limited
Ralph Cordey	Airbus UK
Peter Aspden	Airbus UK
Name withheld	ALBORA Technologies Limited
Martin Jones and Craig Jacobs	ARGANS Limited
David Taverner	Caribou Digital Limited (UK)
Stephen Jones	Celestia Technologies Group (UK) Limited
Sophie Pittner	CGI IT UK Limited
Stephen Vance	CGI IT UK Limited
Jaime Reed	CGO IT UK Limited
Name withheld	ClearSpace
Peter Anderson	Clyde Space
Phil McLachlan	D-CAT
Simon Reid	D-Orbit
Chris Brunskill	D-Orbit
Sean Hardacre	Deimos
Emma Kett	Deimos
Martin Ewart	Earthwave Ltd
Marianne Vinje Tantillo	ESA
Ondrej Svab	ESA
Juliette Lambin	ESA
Jorge Amador Monteverde	ESA
Thilo Kranz	ESA
Joana Kamekova	ESA - Commercialisation Officer
Stephanie Willekens	ESA – Economist
Charlotte Mahieu	ESA – Head of Industrial Policy and Economic Analysis Section

Aude de Clerq	ESA – Head of Technology Transfer, and patent Management Unit
Gertrud Talvik	ESA – Industrial Policy Officer
Guenter Hasinger	ESA, Director of Science
Mark Dumville	GMV NSL
Manuel Ángel Ruiz Saldaña	GMV NSL
Aron Kisdi	GMV NSL Ltd
Mark Dumville	GMV NSL Ltd
Mark Dumville	GMW NSL Ltd
Jack Li	Isotropic Systems
Janet Charlton	JCR Systems Limited
Rob Spurrett	Lacuna Space
Francesco Guarducci	Mars Space Limited
Francesco Guarducci	Mars Space Limited
Tony Whyman	McCallum Whyman Associates
David Kenyon	MDA Space and Robotics Limited
Dorothy Evans	Met Office
Tim P Tinsley	National Nuclear Laboratory Ltd
Christine Sams	National Oceanography Centre
Cyrus Larijani	National Physical Laboratory
Cyrus Larijani	National Physical Laboratory
Nigel Fox	National Physical Laboratory
Steve Groom	NERC – Plymouth Marine Laboratory
Professor Carole Haswell	Open University Board member of Space Academic Network (SPAN) Member of UKSA Space Programme Advisory Committee (SPAC)
Professor Andrew Holland	Open University Chair of Space Academic Network (SPAN) Member of UKSA Space Programme Advisory Committee (SPAC)
Dr Konstantin Stefanov	Open University
Jamie Bantock	Open University
Ian Mellor	Power Resources Group Limited
Rhodri A Lewis	QINETIQ Ltd
Lucy Edge, Mike Curtis-Rouse	Satellite Applications Catapult
Craig Brown	SatixFy
Sophie Pittner	SciSys
Alan Thompson	Skyrora
Paul Kiernan	SKYTEK Technology Limited

Josh Western	Spaceforge
Christopher Hill	Spinlock Ltd
Delyth Lloyd Evans	STFC / ESA BIC
William Gault	STFC / ESA BIC
Nelly Offord	Surrey Satellite Technology Limited
Alex da Silva Curiel	Surrey Satellite Technology Limited
Nigel Towers	Thales Alenia Space
Roger Ward	Thales Alenia Space UK Limited
Martin Townend	Thales Alenia Space UK Limited
Roger Ward	Thales Alenia Space UK Limited
Simeon Barber	The Open University
James Parr	Trillium Technologies Ltd
Caroline Harper	UKSA
Ryan King	UKSA
Sue Horne	UKSA
Libby Jackson	UKSA
Andrew Kuh	UKSA
Beth Greenaway	UKSA
Nicola Bolton	UKSA
Avi Leaner	UKSA
Emily Gravestock	UKSA
Henny Abuzaid	UKSA
Derek Smale	UKSA
Mike Willis	UKSA
Andy Proctor	UKSA
Helen Roberts	UKSA
Tony Forsythe	UKSA
James Beoiley	UKSA
Andrew Kuh	UKSA
George Pritchard	UKSA – Chair of ESA Industrial Policy Committee
Chris Noble	UKSA – Chief Communications Officer
Ingmar Kamalagharan	UKSA – Education and Outreach Manager
Jeremy Curtis	UKSA – Head of Education and Skills
Kathie Bowden	UKSA – National Space Skills and Careers
Professor Lucy Berthould	University of Bristol hair of Space Universities Network

Andrea Cammarano	University of Glasgow
Richard Ambrosi	University of Leicester
Professor Massimilano Vasile	University of Strathclyde
Steve Lingard	Vorticity Ltd

Appendix E Bibliometric methodology

Glossary

CAGR	Compound annual growth rate
CDC	Citation distribution chart
CDI	Citation distribution index
CPC	Cooperative Patent Classification
CNSA	China National Space Administration
DID	Difference in differences
DOCDB	EPO worldwide bibliographic data
EPO	European Patent Office
ESA	European Space Agency
ESTEC	European Space Research and Technology Centre
HCPx	Highly-cited publications, top x%
JAXA	Japan Aerospace Exploration Agency
NASA	National Aeronautics and Space Administration
NSPCP	Normalized share of papers cited in patents
ICR	International collaboration rate
ISA	Italian Space Agency
ROW	Rest of world
SI	Specialisation index
TF-IDF	Term frequency–inverse document frequency
UK	United Kingdom
UKSA	United Kingdom Space Agency
US	United States
UKIPO	United Kingdom International Property Office
USPTO	United States Patent and Trademark Office
WIPO	World Intellectual Property Organization

E.1 Introduction

Science-Metrix, now part of Elsevier, has been commissioned by Technopolis Group to develop measures and indicators of research and patent activity using bibliometrics and patent data to feed into the design, development and implementation of a monitoring and evaluation programme for the UK Space Agency's Investments in the European Space Agency. This work has started in February 2021 and bibliometrics data feeding the first iteration of the report has been delivered in February 2022.

This technical document details the various steps taken to build the publication sets that were used in the study, standardize the data, and produce statistics. It includes all required explanations for the important methodological choices linked with the study.

E.2 Databases

E.2.1 Bibliometric database

All bibliometric statistics produced in this study are based on the Scopus database. The Scopus data used were pulled at the end of February 2021. This version of the database was deemed to have complete coverage up to the end of 2020.

The Scopus database provides comprehensive coverage of the scientific literature, with more than 48 million publications[2], covering about 43,000 peer-reviewed journals in 174 disciplines as of February 2022.[3] For each indexed publication, Scopus indexes text information (title, abstract, author-defined keywords), the addresses of all authors, and the citation links that exist between articles. This information enables a quality bibliometric analysis to be conducted.

The document types included in the analysis are articles, reviews, short surveys and conference proceedings. Unless stated otherwise, the tables and figures deriving from Scopus data include all the aforementioned document types.

E.2.1.1 Limitations

A language bias exists in Scopus in that this database mainly includes papers written in English. While this is not problematic for the fields of natural science and engineering, as the majority of their output appears in English, the bias is more pronounced in the social sciences and humanities. Researchers from these fields tend to publish in local journals or books, which are often written in a language other than English and may therefore not be covered by the database. This creates a bias in search results toward research published in English in these fields. Reporters should be transparent about these limitations, while at the same time acknowledging that coverage of Scopus is continuously broadened in an effort to diminish these over time, while at the same time striking a balance between higher coverage and quality of the material covered.

E.2.1.2 Altemetric database

The PlumX Metrics and Overton databases were used as the sources of altmetric information.

PlumX Metrics provide insights into the ways people interact with individual pieces of research output in the online environment. Examples include research being mentioned in the news or tweeted about. These metrics are divided into five categories (citations, usage, captures, mentions, social media) to help make sense of the huge amounts of data involved and to enable analysis by comparing like with like. Included in the database's coverage are platforms such Facebook and Twitter, a selection of blogging platforms, journalistic and news websites, Wikipedia, Reddit, Stack Exchange, and library holding databases.

The Overton database consists of more than 5 million policy documents. These policy documents include white papers from international multi-lateral organisations, as well as guidelines from city councils, parliamentary transcripts, and other classes of the so called "grey literature". Around half of these documents make citations to academic or scholarly publications. Just over 2 million distinct journal-based publications are cited by at least one policy document in the database. As was the case with Scopus, the Overton database does

[2] This is for the production version, which is limited to articles, reviews and conference papers published after 1996. The whole Scopus database going back further than 1996 in time, and with no limitation regarding document types, covers 84 million documents.

[3] https://www.scopus.com/sources.uri

display bias towards English-language documents originating in Anglo-Saxon countries. However, as the only robust database of its kind currently available, its addition to the set of data sources used for this evaluation will lead to valuable insights into knowledge transfer between academia and the policy-making world.

E.2.1.3 Patent database

Data for this study were prepared using the PATSTAT 2020 Autumn edition, released in October 2020.

PATSTAT, a product of the European Patent Office (EPO), contains bibliographic data from more than 100 million patent documents, covering 90 patent authorities, from both industrialised and developing countries. Over the years, it became a point of reference for patent analysis, emerging as the most frequently used database for scientific research (based on searches in bibliographic databases of scientific publications). Its exhaustive coverage enables users to prepare various analyses, and its content is frequently enriched following work from the community.

In this study, patents filed at the UKIPO, USPTO, EPO, and/or WIPO were included.

E.3 Construction of the publication and patent sets

E.3.1 Space science (thematic) publication set

One of the first tasks to be conducted in this project was the identification of all publications that were focused on space science. At the time of building this publication set, the area was defined as having a focus on space technologies (e.g., satellites, space probes) and research on space but done from space and not from Earth (e.g., the International Space Station and space telescopes).

Multiple complementary approaches were used to construct this publication set. First, a set of keywords relevant to the field was developed. This was done using an iterative approach which started from collecting a set of documents including words from a limited list of keywords related to space science. This first search was confirmed to return very few false positives[4]. Then, a text-mining approach based on the term frequency-inverse document frequency (TF-IDF) method was used to collect a list of additional keywords that were specific to these publications. These additional pertinent keywords were added to the search, and then the same cycle was repeated until very few articles were being added to the publication set between every iteration.

Examples of keywords used to build this publication set are:

- Airborne telescope
- Artificial satellite
- Astronomical satellite
- Satellite imagery
- Satellite link
- Satellite navigation
- Space application

[4] A false positive here is considered to be any publication not related to space science that gets included in the space science thematic publication set.

- Space industry
- Space mission
- Space probe
- Space technology
- Space telescope
- Spaceflight
- Use(d) in space
- …

The publication set was however not solely built using keywords. To improve coverage in an efficient manner after the keyword search stage was completed, SciVal topics[5] were also used to identify additional pertinent articles. SciVal topics are defined using citation patterns between publications at the level of the entire Scopus database. Simply put, the articles in a given topic cite each other more so than they cite publications outside of the topic. This makes topics collections of publications that very likely share a common scientific interest. This also makes topics mutually exclusive, hence every Scopus-indexed publication can be included in a single topic at a time. To help increase the recall of the publication set, we first measured the proportion of every topic that was already returned by the keyword query described above. Based on their definition, we know that topics that have an elevated share of their publications already included in the publication set are likely to be pertinent as-a-whole for the space science thematic publication set. The question that remained was where to set the threshold above which the full contents from a topic would be included in the thematic publication set. To answer this question, we rated the pertinence level of a sample of articles that would get included for different thresholds. In the end, we found that precision was satisfactory (97% of all articles were on-topic) up to the 20% threshold and then it fell rapidly. Therefore, the 20% threshold was used in producing the publication set. This signifies that the contents of all topics that had at least 20% of their content present in the keyword-based query got fully included in the thematic publication set, supplementing the results from the keywords-based approach.

For all analyses that were based on this publication set, all impact indicators (§E.5.2) were renormalized at the level of this publication set. For example, this makes it so that the World FWCI is exactly 1.00, making it easier to know how a given country performs relative to the world level.

E.3.2 ESA-related publications

ESA-related publications, which are those that share a link to the ESA through funding, authorship or use of ESA-related equipment or data, was the second publication set that needed to be constructed. Once again, multiple complementary approaches were used to build this publication set. They are summarized in the following list:

1. For every publication that has such information indexed in Scopus, **funding acknowledgements** were searched for mentions of **ESA** or its affiliated institutions (e.g., ESTEC).
2. Mentions of **ESA** or its affiliated institutions were searched for in the **titles, abstracts and keywords** of all publications

[5] For more information about SciVal topics, see https://www.elsevier.com/solutions/scival/features/topic-prominence-in-science

3. Any publication in which at least one of the authors had an **ESA affiliation**.
4. Mentions of **space missions** in which ESA was involved were searched for in the **titles, abstracts and keywords** of all publications. Both the shortened and full names were used in the search.
5. Existing **lists of publications that are linked with ESA missions** were searched for in Scopus. These lists include the Researchfish data provided by Technopolis as well as the lists extracted from the ADS public library[6].

Any publication that matched one or more of these criteria was considered to be "ESA-related". Do note that as mission names sometimes use names or acronyms that form words otherwise unrelated to the missions, some searches had to be restricted or omitted altogether. A few examples of these follow:

- The Solar and Heliospheric Observatory mission uses the acronym "SOHO". Soho is also the name of a New York City neighborhood, and an acronym used in buildings-related research to signify "Small office, home office" which means using only the acronym in a search returned a high proportion of false positives. To limit these, we searched for "Soho" in conjunction with terms such as "Sun" or "Solar", which improved precision but may have dropped a few articles that did not also use one of the limiting terms in the title, abstract or author-defined keywords of the article.
- The Infrared Space Observatory mission uses the acronym "ISO". ISO is also the acronym used to denote the International Organization for Standardization, and a search that uses only ISO returns far more publications about ISO standards than the space mission. Even limiting with keywords proved unsuccessful, as the quantity of false positives was still too high, such that this acronym was dropped from searches entirely. Text searches were still conducted with the full name of the observatory, which should capture most of the relevant output given that it is very rare that only acronyms are used in the abstract, especially when there is significant risk for confusion. The other search strategies all still apply to this mission as normal too.

Identifying publications related to specific ESA programmes

To enable the computation of indicators at the level of the ESA main programmes, ESA-related publications were also assigned to the ESA programme to which they are relevant whenever this was possible. To ensure majximum precision in this mapping exercise, only these publications that were linked with one or more missions were eligible to be assigned to an ESA programme. Therefore, publications that were included in the ESA-related publication set only because they had an ESA affiliation, an ESA funding acknowledgement or an ESA text mention were not mapped to a programme. Publications that did not map to a given mission area are however still included in the overall "ESA-related" publication set.

The eight ESA programmes are:

- Space Science
- Earth Observation
- Human and Robotic Exploration
- Telecommunications & Integrated Applications

[6] These lists are publicly available here: https://www.cosmos.esa.int/mission-publications

- Navigation and Innovation Support
- General Support Technology Programme
- Space Safety and Security
- Space Transportation

All missions that returned publications were mapped to one of these programmes using the mapping list provided by Technopolis and the publicly available information found on the ESA website[7].

E.3.3 Other publication sets

A few other publication sets were used to produce national statistics. Those sets were created solely by using scientific subfields as defined by Science-Metrix classification scheme. All subfields that share a link to the topic of space science were provided as separate publication sets, each with its own statistics table in the databook.

The selected subfields were:

- Aerospace & Aeronautics
- Astronomy & Astrophysics
- Geological & Geomatics Engineering
- Industrial Engineering & Automation
- Meteorology & Atmospheric Sciences
- Networking & Telecommunications
- Optoelectronics & Photonics

E.3.4 Space science patents

The space science patent set was built with a similar focus as the thematic publication set (§E.3.1). It started from a similar set of keywords as the one defined above, which was then iteratively built using the same method based on TF-IDF analysis. Given the unique challenges linked with patents, namely the relatively vague nature of the words used in titles and abstracts (or the absence of these elements from PATSTAT altogether), expanding coverage through another, non-keyword-based method was mandatory.

To serve this purpose, CPC categories were used to include additional patents that couldn't be captured through keywords, much in the same way as was done for publications with Topics. A notable difference is that patents can be attributed to multiple CPC categories simultaneously, while publications could not have been attributed to multiple topics. To adapt to this difference, the CPC inclusion process was also an iterative one. After including a certain number of relevant classes, the share of patents from each class that was captured by our search was recomputed, which could then highlight new pertinent classes.

E.4 Institutional profiles

E.4.1 Harmonization

This project necessitated the computation of bibliometric and technometric statistics at the institutional level for the institutions with the highest quantity of output. There is an additional

[7] https://www.esa.int/ESA/Our_Missions

complexity inherent to this kind of analysis as different institutions and researchers may use different names, which then all need to be identified as belonging to the same entity to enable accurate data computation. To ensure the highest standard of quality for these data, manual work was undertaken to ensure that all of an entity's publications are rightfully attributed to them.

Examples of the cases covered by this exercise are variations in the spelling or amount of information provided, for example publications attributed to "Cambridge university", "University of Cambridge", "U. Cambridge" and "University of Cambridge, Department of Engineering" all need to be regrouped under a unique name to enable accurate statistics to be produced.

Other cases include large institutions that are split across many institutes, divisions and departments and for which the name of the overarching organization may not have always been provided as part of the address field. For example, "European Space Research and Technology Centre (ESTEC)" is an affiliation that was attributed to the parent entity "European Space Agency". This can also be a particular issue for large corporate entities that are the owners of subsidiaries. In such cases, efforts are made to attribute the sub-entities' publication output to the portfolio of their main entity, by manually searching for company names and attributing them to their parent company should they be a subsidiary. For example, all publications and patents by "Astrium Ltd." are attributed to their parent company "Airbus".

The status of companies at the time of the cleaning exercise was used for the full period of analysis. For example, if company A acquired company B in year 2015, then the publications written by company B from 1996 to 2014 still get attributed to company A. This way of attributing publications makes the analysis of time trends more consistent. In the case of patents, it is also generally more representative of the current ownership of patents.

The harmonization exercises were conducted prioritizing institutions with larger outputs over those with smaller ones and progressively going down the list, either until the chance of an institution being included in the list of most productive ones was low (meaning that even if the portfolio were extremely fragmented, it became unlikely to be included in the top-producing institutions given the gap in publication numbers), or the number of publications/patents became too low (typically, ≤10 is the threshold at which harmonization is stopped for areas that otherwise have reasonable amounts of output.).

An exception to this harmonization method was made to identify patents for all ESA-funded institutions. Technopolis provided Science-Metrix with a list of all these institutions, which was used to search through the PATSTAT database using a fuzzy-matching algorithm. This allowed the identification of additional companies than those that were found in the worldwide analysis (because their patent output was below the threshold at which harmonization was halted). However, given the elevated number of companies, no manual work past the validation of matches was done on these profiles. Therefore, subsidiaries were not reattached to these profiles and names, and recall can be lower than with manual harmonization if PATSTAT-indexed names were too different from the names Technopolis provided. In the current version of the databook, this limitation applies only to "Table 34 - Institutional technometric indicators for all ESA-funded institutions with patenting activity in the field of space science".

E.4.2 Sector coding

In some tables, statistics were provided for the private and public sectors. This information is based on a semi-automated sector coding approach. In this approach, all institutions are considered either "public" (public or for-profit universities, non-for-profits, governmental institutions) or "private" (corporations, state-owned for-profit enterprises).

In a first step, author addresses belonging to the private sector in Scopus were identified using an automated algorithm.

This algorithm consisted of the following steps:

- **Step 1:** Coding of various forms of public organisations using generic terms (e.g. university, univesität, universidad, université, faculty, school, government, ministry).
- **Step 2:** Coding based on a curated and exhaustive thesaurus of companies from around the world from sources such as the Global Research Identifier Database[8] and Scopus institutional affiliation tagging
- **Step 3:** Amending the list to include the firms listed in the 2012 EU Industrial R&D Scoreboard
- **Step 4:** Amending the list to include the private companies listed in CORDA
- **Step 5:** Additional coding with the help of reliable filters based on types of business entities defined in the legal systems of various countries (e.g. Corp., Pty, Ltd, Inc, S.A., AB, GmbH, SP, GP, LP)
- **Step 6:** Searching the database for the names of companies identified in the previous step, using a shorter form without the specific term (e.g. Inc., LLP, GmbH) – for example, if 'Boehringer Ingelheim GmbH' is retrieved in step 5, then a search for 'Boehringer Ingelheim' is performed in the database

A sample of addresses that were coded to the public sector and a sample of addresses coded to the private sector were validated manually to assess the precision and recall of this method. On a random sample of 200 addresses coded as private entities, we measured an estimated precision of 97 % or 194/200. A random sample of 200 addresses that were not coded as private was also taken. In this case, 100 % of addresses did not meet the criteria for private entities, that is organisations that are for profit or engage in activities like those of for-profit companies.

A few instances of miscoded corporations were then manually corrected.

E.5 Publications: indicators

E.5.1 Bibliometric indicators: Outputs

Number of publications, using full counting and fractional counting

This indicator shows the number of publications for a given entity, calculated using a method called *full counting*. Using this method, each country or research organization that has a researcher on the list of authors for a given paper gets a full count (1 publication) for that paper. For example, if a paper is authored by two researchers with addresses in the United Kingdom, one from Spain and one from the United States, the paper will be counted once for the United Kingdom, once for Spain and once for the United States.

An alternative method, known as fractional counting, divides publications based on the proportion of authors from a country contributing to an article. For instance, if a paper lists two authors with addresses from the United Kingdom, one from Spain and one from the United States, the publication is divided into four parts, with the United Kingdom receiving two of these parts (0.5 publication), Spain receiving one (0.25 publication) and the United States receiving the fourth part (0.25 publication).

[8] https://www.grid.ac/

Data based on full counting indicate only which countries are involved in the production of an article, whereas fractional counting provides an indication of the share of work contributed by a given country. However, both these methods of counting attribute equal credit to all authors.

Compound annual growth rate (CAGR)

The compound annual growth rate (CAGR) measures the rate at which a given entity's production changed over a number of years, taking compounding effects into account. For instance, if an entity's output increases by 6% every year, then after 12 years of compounded growth (also known as *exponential growth*) its output total will double. Because the CAGR is a single number that does not communicate information on the yearly fluctuations within a trend, output trend data for each entity is also included as a bar graph in the results tables.

E.5.2 Bibliometric indicators: Impact

All indicators of scientific impact used in the report are based on citations. An important assumption underlying such analyses is that citations are a good proxy for contributions to scientific knowledge. While it is true that citations are generally used to communicate the positive influence of one piece of research on another, citations are also sometimes used for other reasons. For example, one article may be contradicting another; the author would in that case use a citation to highlight the article being contradicted. Additionally, an article may cite many others, with some material constituting general background information and other material constituting the principal foundation on which the new piece of knowledge is built. These varying citation behaviours are all treated equally in analyses of scientific impact, which are blind to the differences between them.

Scientific impact assessed on the basis of citations would therefore be better interpreted as contributions to and visibility within scientific discourse. In light of this, the interpretation of scientific impact analyses should proceed with due caution.

Relative citation (RC) scores

Counting citations can be used as a proxy for measuring contributions to subsequent knowledge generation; however, because citation practices vary between the disciplines and sub-disciplines of science, simple counting would create unwanted biases in the results. To correct these potential distortions, individual publications are evaluated relative to the average citation rate for publications in the same field or subfield and published in the same year; the normalization also accounts for the type of publication because review articles are usually more cited and include more references than journal articles.[9] This measure is known as the relative citation (RC) or field-normalised citation and will not be used directly in this study's analyses. Rather, it is instrumental in computing the field-weighted citation index (FWCI) and the highly cited publications (HCP) presented below.

For all the indicators relying on the RC scores of papers, a certain amount of time must be allowed for the published work to have an impact on subsequent research and for articles to be cited. Ideally, we keep a minimum of two years following the latest year of publications, meaning that in this case, papers published after 2018 are not attributed relative citation scores and are thus not taken into account when computing the impact indicators.

[9] For all citation-based measures, a certain amount of time must be allowed for the published work to have an impact on subsequent research, and for articles to be cited. Accordingly, impact measures for the present study can be computed for articles published in 2018 or earlier. Papers published in 2019 or later have not had sufficient time for citations to accrue.

Field-weighted *citation index (FWCI)*

The field-weighted citation index (FWCI) is the average of the relative citation scores of all the articles published by a given entity. The FWCI is normalized to 1, meaning that an FWCI above 1 indicates that the entity's articles have higher-than-average impact, an FWCI below 1 means that the entity's articles have lower-than-average impact, and an FWCI near 1 means that the publications have near-average impact.

Because RC scores are known to be skewed in their distribution—with a small number of papers receiving a large share of the total citations—the FWCI offers a useful snapshot of overall performance but can hide important underlying nuance. For this reason, Science-Metrix proposes to complement the FWCI with the HCP described below.

Citation *distribution index (CDI)*

The citation distribution index (CDI) tool facilitates a simple inspection of an entity's research impact relative to worldwide performance. To prepare this indicator, Science-Metrix divides all publications in a given research area into 10 groups of equal size, or "deciles,"10 based on their RC scores. The 1st decile contains the 10% of publications with the lowest RC scores; the 10th decile contains the 10% of publications with the highest RC scores.

For a given research entity, it is expected that the RC scores of its publications will follow the global distribution, with an equal number of publications falling in each of the deciles. Ideally, one would hope to have more papers than expected in the highest deciles, where the most impactful publications are found; similarly, one would hope to have fewer papers than expected in the lowest deciles, where the least impactful publications are found.

This distribution of impact can be summarized numerically using the CDI. For each decile, the performance of a given research organization is compared to the global average, and this ratio is then multiplied by a weight corresponding to that decile, as presented in Table .

Table 3 Decile weighting to compute citation distribution index

Decile	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Weight	-5	-4	-3	-2	-1	1	2	3	4	5

Source: Prepared by Science-Metrix

Once a score has been produced in this fashion for each decile, the scores are summed to calculate the CDI for the research organization. Thus, having a higher-than-expected number of publications in the 1st decile (i.e., the lowest-impact decile) will reduce the CDI more than having a higher-than-expected number of publications in the 2nd decile. The CDI ranges from -50 (worst-case scenario) to 50 (best-case scenario) with 0 representing parity with the world level. Compared to mean-based normalized citation metrics, the combined use of the CDC and CDI makes it possible to provide reliable citation metrics even when dealing with entities having produced few publications (from 10 to a couple of hundred).[11]

[10] Two adjustments are made in order to ensure high-quality results, and these pertain to (a) cases where a number of publications are tied in their scores, and (b) cases where the total number of publications is not divisible by 10. For the first case, (a), papers tied at the margin of two deciles will be grouped together and then divided proportionately to ensure that each decile contains the right number of papers. In the case of the total number of papers not being divisible by 10, (b), papers will be fractioned to ensure that the deciles are always of exactly equal size.

[11] Campbell, D., Tippett, C., Côté, G., Roberge, G., & Archambault, É. (2016). An approach for the condensed presentation of intuitive citation impact metrics which remain reliable with very few publications. In I. Rafols, J.

Highly cited publications (HCP)

Highly cited publications (HCP) are publications that received relative citation (RC) scores among the highest in their respective field; for this study, the top 10% and top 1% most cited publications were selected. This indicator is frequently used to examine research excellence, measuring how many high-impact articles are produced by a given research entity, relative to their expected contribution to world-leading research.

In this project, the HCPs were provided as shares, such that values should be compared with the expected values of 10%, 5% or 1%, respectively.

E.5.3 Collaboration

International collaboration rate (ICR)

An international co-publication is defined as any article that was co-published by authors from at least two countries. The international collaboration rate (ICR) of a country is simply a measure of how many articles are co-published with international partners as a proportion of the given country's total output.

International collaboration plays a different role in the research ecosystems of large and of small nations. For instance, in looking for complementary expertise, a researcher in a small market may have no choice but to look for international partners for research collaboration, whereas a researcher in a larger market may be able to find the complementary skill set without looking outside national borders. For example, Poland and California have roughly the same population, but a Polish researcher collaborating with a researcher from another EU country (Germany, for instance) counts as an international collaboration, while a researcher from California can form domestic partnerships with researchers in other US states, which do not count as international collaborations. Such differences are accentuated further as one examines smaller countries, where the need for complementary expertise more often necessitates international partnership.

ICR (ESA) and ICR (ROW)

In this project, special versions of the ICR looking at collaboration with subsets of countries were also computed. Two such subsets were devised: ESA members, and non-ESA members. There are currently 22 ESA members. They are:

- Austria
- Belgium
- Czech Republic
- Denmark
- Estonia
- Finland
- France
- Germany
- Greece
- Hungary
- Ireland
- Italy

Molas-Gallart, E. Castro-Martínez, & R. Woolley (Eds.), *Proceedings of the 21st International Conference on Science and Technology Indicators*, pp. 1229–1240. Valencia, Spain. doi:10.4995/STI2016.2016.4543.

- Luxembourg
- Netherlands (the)
- Norway
- Poland
- Portugal
- Romania
- Spain
- Sweden
- Switzerland
- United Kingdom (the)

The special versions of the ICR denote what percentage of publications were written in collaboration with at least one ESA-member state, and what percentage was co-written in collaboration with at least one non-member state. A publication can fall into both categories at the same time, for example if it involves two ESA members and a non-member. To avoid making the computation useless, these rates exclude the country for which the rate is measured. For example, a publication that was co-written by an author from the United Kingdom and one from the United States would *not* be counted as an ESA international collaboration for the UK because the US is not an ESA member state. This is despite the publication being internationally co-written and the UK being an ESA member. The same publication would however count as an international collaboration with an ESA member for the United States.

E.5.4 Share of papers cited in patents (SPCP)

This indicator corresponds to the proportion of papers that have been cited in at least one patent application from any of the offices covered in the PATSTAT database. One should however be aware that patent citation information is complete for patents submitted to the USPTO and the EPO but is lacking for most other offices. Asian countries, for example, may then be at a disadvantage for such indicators. In this version of the indicator, patent applications that were rejected, that are still being treated, or that led to the granting of patent are all included. This was done to maximize signal, as the time elapsed between the initial patent application and its granting is typically of the order of more than five years. Given that the articles of interest in this study were published quite recently, limiting to only granted patents would have rendered this analysis very unreliable.

The proportion of articles in a given publication set to have been cited at least once by a patent can provide an approximation of the levels at which the corresponding research is "technology-relevant", or, more broadly, conducive to knowledge transfer.

It should be noted that this indicator can typically only be meaningfully deployed in a retrospective analysis conducted well after the periods of interest. Indeed, most patents with a reasonable probability to cite a given publication are expected to be published seven years or so after the issue of that given publication. Also, this indicator provides no signal as to whether the citing patents are themselves associated with successful, durable innovations.[12] Therefore it measures uptake in technological practices, but not research transfer into successful innovation in the broadest sense.

[12] van Raan, A. F. J. (2017). Patent Citations Analysis and Its Value in Research Evaluation: A Review and a New Approach to Map Technology-relevant Research Science. *Journal of Data and Information*, 2(1). doi:10.1515/jdis-2017-0002.

In the case of this study, the required period has not elapsed for most paper publication years. Thus, the decision was taken to present the raw share of papers cited in patents (SPCP) along with a year normalized share of papers cited in patents (NSPCP) for all years from 1996 to 2018. The NSPCP is computed by dividing the SPCP of a given entity by the world's SPCP in the same field for the same year. Although the shares themselves are certainly not yet stable and will be subject to change as the base data are updated, this may provide an early look at high-level trends and enable the identification of very early uptake of research in patents. Any conclusions would however need to be supported by other lines of enquiry to ensure their reliability at this early stage.

E.5.5 Altmetric indicators

In the decade spanning 2010–2020, a novel research evaluation tool emerged with the launch of databases recording the uptake of scientific outputs beyond the scientific literature in, for example, social media, blogs, news, policy documents and educational resources. These data, because they track usage beyond the traditional academic circles as traditionally captured in bibliometric indicators, are often referred to as alternative metrics (or altmetrics). Altmetrics aim to measure the visibility of peer-reviewed scientific publications in policy citations or on social media by looking at mentions (or usage statistics) of these items on Twitter, Facebook, Mendeley, and in blogs. These mentions are usually tracked through document identifiers such as DOI, PMID and the URL of the article. Altmetrics have seen widespread uptake with scientific publishers. For example, PloS ONE article pages track Mendeley library saves, Twitter retweets, Facebook shares, the count of views on the website, and others. Nature also presents an Altmetrics score on its articles' pages, which can be decomposed in tweets, Facebook mentions, news outlet mentions, blog mentions, and so forth.

The value of social media mentions to journal articles is that they may capture degrees of readership, uptake and engagement, in an audience that is theoretically not restricted to peers. As an expert group on altmetrics convened by the European Commission contended:

> *Altmetrics also have potential in the assessment of interdisciplinary research and the impact of scientific results on the society as a whole, as they include the views of all stakeholders and not only other scholars (as with citations). Hence, altmetrics can do a better job at acknowledging diversity (of research products, reflections of impact etc.), providing a holistic view of users as well as providers of scientific products, and enhancing exploration of research results.*[13]

Further, the same group summarizes the potential advantages of altmetrics as: broadness (inclusion of multiple stakeholder types), diversity (type of outputs measured), multi-faceted (different signals for a given output), and speed (readership of an article typically taking place faster than the uptake of its findings in ulterior research).

Science-Metrix has also been able to make certain observations on the limitations of altmetrics as part of previous research evaluation projects. The value of these mentions, given how general a 'mention' is as a category, is hard to interpret meaningfully on its own. It might be argued that the audience for the discussion of scientific findings on social media is made up of scientists, rather than or as much as of the lay public. Additionally, it should be kept in mind that members of a research team may themselves refer to their own research on their social media pages. In this case, altmetric 'citations' are more representative of self-promotion than

[13] European Commission Expert Group of Altmetrics. (2017). *Next-generation metrics: Responsible metrics and evaluation for open science*. Brussels, p. 11.

broad societal uptake. Disaggregating altmetric citations by source and using different metrics within each source may help to distinguish between cases of self-promotion and uptake.

Mentions in news outlets or on Wikipedia can more safely be assumed to amount to broad uptake, for instance. Similarly, indicators based on highly mentioned publications may be less sensitive to self-promotion, compared with indicators based on the share of publications mentioned in a specific altmetric source, except perhaps for publications with many authors such as those resulting from research consortia. Accordingly, additional normalisation by number of authors might be desirable to properly control the effect of self-promotion. Further qualitative research would be needed to inform such decisions. Social media-based altmetrics have not yet been widely deployed in programme evaluations.

In this study, four indicators were computed. They are fundamentally similar, as all four are simple binary (cited/not cited) indicators not sensitive to the quantity of citations of each type received by each article. This decision is typically taken when working with altmetrics as it can otherwise be difficult to reliably control for various effects (much more so than scientific citations).

The fours indicators are:

- The share of articles cited in at least one policy document
- The share of articles cited in at least one Facebook post
- The share of articles cited in at least one Twitter tweet
- The share of articles cited in at least one Wikipedia article

E.6 Technometric indicators

E.6.1 Application and patent counts, full counting and fractional counting

Full and fractional counting are the two principal ways of counting the number of applications and patents originating from a given country, organisation, or other entity. The difference between an application and a patent is that an application has only been filed at a patent office and may still be pending or not have been granted, while a patent has indeed been granted. Counting methods are the same for both.

In the full counting method, each patent is counted once for each entity listed in the address field (either for inventors or applicants depending on the statistic being prepared). For example, if two inventors from the US and one from Canada were awarded a patent, the patent would be counted once for the US and once for Canada. The same method applies for applicants. If a patent is assigned to Microsoft in the US, IBM in the US and Siemens in Germany, the patent will be counted once for Microsoft, once for IBM and once for Siemens. It will also be counted once for the US and once for Germany. When it comes to groups of institutions (e.g., research consortia) or countries (e.g., the European Union), double counting is avoided. This means that if inventors from Croatia and France are co-awarded a patent, when counting patents for the European Union this patent will be credited only once, even though each country will have been credited with one patent count at the country level.

Fractional counting is used to ensure that a single patent is not counted several times. This approach avoids the use of total numbers across entities (e.g., inventors, organisations, regions, countries) that add up to more than the total number of patents, as is the case with full counting. Ideally, each inventor/applicant on a patent should be attributed a fraction of the patent that corresponds to his or her level of participation in the invention process compared to the other inventors/applicants. Unfortunately, no reliable means exists for calculating the

relative effort of inventors/applicants on a patent, and thus each is granted the same fraction of the patent.

In the first example presented for full counting (two inventors with addresses in the US, one inventor located in Canada), two thirds of the patent would be attributed to the US and one third to Canada when the fractions are calculated at the level of addresses. Using the same approach for the applicants presented in the other example (one address for Microsoft in the US, one for IBM in the US and one for Siemens in Germany), each organisation would be attributed one third of the patent.

In this study, to simplify the tables, counts are only presented in full counting. However, fractional counting is used to compute the specialization index and growth rates.

DOCDB application and patent families counts

A DOCDB patent family is a series of patent applications related to the same technical content. The applications of a patent family are linked to each other through priority claims. There are multiple methods available to delineate patent families. One type is referred to as DOCDB patent families, which creates patent families of patents sharing the exact same priorities.

Simply put, a DOCDB application/patent family collects all applications made at all offices that pertain to a single invention. Therefore, counting families is a better indicator of number of inventions than counting individual application/patents numbers. In this project, a DOCDB patent family is simply a DOCDB application family in which there is at least one granted application at any office.

Specialisation index in patenting

The specialisation index (SI) indicates how much emphasis a given entity puts on one field, relative to the reference (regional or global) average of effort exerted in that field. For instance, if 20% of a given country's patents are in optics, but at the global level only 15% of papers are in optics, then the country is said to be specialised in optics, putting more emphasis on that field than is normally the case elsewhere around the world.

The SI reference value is 1; accordingly, an SI above 1 shows that an entity invests proportionately more effort than the average in a given area, an SI below 1 shows that an entity invests proportionately less effort than the average in that area, and an SI near 1 shows that an entity invests close to the average proportion of effort in that area. It is worth noting that the SI is a zero-sum game, as it is measured as a proportion of total output. If the proportion of an entity's output in one area increases, there must be relative decreases elsewhere.

Appendix F Economic assessment methodology

F.1 Direct and indirect effects (Cambridge Econometrics Methodology, E3ME)

The macro-econometric analysis used data on spending projections for 2020-25 for each ESA programme, which we disaggregated by industrial sector and used as inputs into Cambridge Econometrics' E3ME model.

The spending projections for the four largest programmes, as well as the total portfolio spend, were each used as inputs into separate ex-ante modelling scenarios, which were compared to a counterfactual 'baseline' forecast in which none of the UKSA spending occurred. Comparing the model results for these programme scenarios against the baseline allows us to estimate the macro-economic impacts of the programme spending across the wider economy.

This methodology is described in more detail in the sections below.

F.1.1 The E3ME model

E3ME is a global, macro-econometric model of the world's economic and energy systems and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used for policy assessment, forecasting and research purposes across different geographical areas.

As a general model of the economy, E3ME is capable of producing projections for GDP and the aggregate components of GDP (household expenditure, investment, government expenditure and international trade), and other output indicators including employment by sector and GHG emissions.

The structure of E3ME is based on the system of national accounts, with further linkages to energy demand and environmental emissions. The labour market is also covered in detail, including both voluntary and involuntary unemployment. In total there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

E3ME's historical database covers the 1970-2018 period and the model projects forward annually to 2050. The main data sources for European countries (including the UK) are Eurostat and the IEA, supplemented by the OECD's STAN database and other sources where appropriate. Economic forecasts are based on projections from the IMF World Economic Outlook (in the short term) and the IIASA SSP2 (in the long-term). For regions outside Europe, additional sources for data include the UN, OECD, World Bank, IMF, ILO and national statistics. Gaps in the data are estimated using customised software algorithms.

The economic submodule of E3ME used for this project has the following dimensions:

- 70 regions – all major world economies (i.e. G20), the EU28 and candidate countries plus other countries' economies grouped
- 70 industry sectors, based on standard international classifications
- 43 categories of household expenditure

For more information on the E3ME model, including the model manual, please visit www.e3me.com.

F.1.2 Scenario design

The E3ME modelling consisted of an ex-ante analysis of the macroeconomic impacts of projected UK spending under each of the four largest ESA programmes:

- Science programme[14]
- Earth observation
- Human and robotic exploration
- Telecommunications and applications

A fifth scenario analysed the impacts of total portfolio spending across all eight ESA programmes, including the above four as well as a further four smaller programmes:

- Launch[15]
- Navigation
- Technology
- Space Safety
- Basic Activities (part of Mandatory Activities)
- Guiana Space Centre (part of Mandatory Activities)

The spending projections in each programme heading were disaggregated by sector, using a methodology described in the next section. These disaggregated spending commitments were introduced into the model scenarios as an assumed increase in gross output for the respective sectors. This approach effectively assumes that the spending is funded from an expansion of UK government spending, without any corresponding pay-fors or budget balancing.

The disaggregation of spending inputs allowed for a detailed analysis of the supply chain effects of this spending. The analysis only aimed to capture the impact of Type I multipliers of UKSA investment in ESA (which is returned through ESA spending commitments) on the wider economy. We therefore adjusted the E3ME model to remove the calculation of induced consumption (Type II) effects. It's also worth noting that by only modelling ESA spend on UK commitments and not ESA spend in other countries, the modelling does not capture the impact of ESA spending in other countries on demand for UK exports.

Outcomes for the five scenarios, with the spending commitments included, were compared against a baseline economic forecast with none of the spending commitments included. Scenario results are reported in terms of differences from the baseline outcome; these differences represent the estimated impact of the spending commitments alone.

F.1.3 Scenario input processing

The only model input in each scenario is a breakdown of the projected ESA spending commitments to the UK by economic sector, over 2020-25. We calculated these sectorally disaggregated spending commitments using three key data sources:

[14] The Science programme is part of the larger ESA "Mandatory activities and science" programme; in this modelling exercise we have excluded the spending on "Mandatory activities".

[15] We have also excluded spending on the "Space Rider PRIDE" programme from the "Launch" programme.

- The **ESA geo-returns dataset**, which comprises data on ESA contracts to UK firms, awarded in accordance with the geographical return principle, whereby member states receive the majority of their CMIN contributions back in the form of industrial contracts.[16]
- The **Companies House dataset**, indicating UK SIC (2007) codes for sector of economic activity, postcodes, and other information for listed companies in the UK.[17]
- The **ESA Contributors' Financial Obligations report dataset**, indicating spending projections by country under each ESA programme, for the 2020-25 period.

We first calculated the share of total contract values awarded to firms in each SIC 2-digit sector for each ESA programme, by linking the geo-returns dataset to the Companies House dataset using company names. We then used these sectoral shares by programme to estimate the sectoral split of the spending projections, which we sourced from the Financial Obligations dataset.

Our first step was to use the geo-returns data to calculate the share of total contract values awarded to firms in each SIC 2-digit sector under each programme heading. We achieved this by linking the geo-returns dataset to the Companies House dataset using company names.

We first summed the total value of contracts (awarded in 2016-21) for each company and programme in the geo-returns data. We then matched the resulting list of 541 company names to the Companies House data. Of these, 412 names matched exactly between the two datasets after some basic data cleaning. A further 36 companies were individually matched following some basic internet searches to establish matching companies (mostly companies who had undergone a name change, or were listed in one dataset or the other under an acronym).

For these 448 companies which *were* listed in both the geo-returns and Companies House datasets, we matched contracts from the former to SIC codes (aggregated to the two-digit level) listed in the latter. In some cases, a single company was associated with more than one SIC code; in these cases, we split the company contract value among the different SIC codes according to the relative share of UK GVA in 2019 among these SIC codes.

This left 93 organisations in the geo-returns dataset which were not listed in the Companies House data, because they fell into a category not covered by the latter dataset: universities, charities, government agencies and departments, international organisations, and foreign-registered companies. For these organisations, we manually assigned SIC codes according to the category they fell in, as follows:

- Universities: 72 Scientific research and development[18]
- Charities: individually matched
- Government agencies and departments: 84 Public administration and defence
- International organisations: 99 Activities of extraterritorial organisations and bodies
- Foreign-registered companies: individually matched

[16] Note that the geo-returns dataset includes contracts from both the CMIN16 and CMIN19, but does not distinguish between these. In the absence of further information, we treat these two CMINs the same. We therefore effectively assume that there are no structural differences between them, and that the distribution of value across sectors in the CMIN16 contracts will be carried forward into the CMIN19 contracts.

[17] The Companies House data is available for download at: http://download.companieshouse.gov.uk/en_output.html

[18] Activities of universities could equally be classified under *85 Education*, but we have assumed the contracts under the ESA programmes were awarded specifically for R&D work.

Having assigned SIC codes to the organisations in the geo-returns data, we calculated the share of total contract values awarded by SIC code for each programme.

The outcomes from this task are summarised in Table 1. This table provides a breakdown of contract values awarded over 2016-21 for each of the four largest ESA programmes (with an aggregate figure for the other four programmes), and for each of the top ten sectors by value (with an aggregate figure for other sectors). Sectoral shares for each programme are also indicated in brackets.

Table 1 Geo-returns contract value by programme and SIC code (2-digit), 2016-21

€ million (% of programme total)	Science	Earth observ-ation	Explo-ration	Telecoms	*Other progra-mmes*	**Total**
23 Other transport equipment	27.2 (14)	101.5 (36)	188.7 (74)	48.2 (14)	14.3 (11)	379.9 (32)
19 Computer, optical & electronic	67.4 (35)	42.6 (15)	3.5 (1)	43.1 (13)	9.8 (8)	166.4 (14)
42 Telecommunications	4.1 (2)	20.9 (7)	2.4 (1)	109.0 (32)	11.9 (9)	148.3 (12)
51 R&D	29.1 (15)	24.8 (9)	22.6 (9)	22.8 (7)	16.7 (13)	115.9 (10)
50 Architectural & engineering	19.3 (10)	21.9 (8)	8.4 (3)	15.4 (5)	23.3 (18)	88.3 (7)
43 Computer programming, info services	9.7 (5)	16.8 (6)	7.6 (3)	33.7 (10)	6.1 (5)	73.9 (6)
53 Other professional	12.6 (6)	19.4 (7)	4.6 (2)	11.5 (3)	14.3 (11)	62.3 (5)
58 Public administration & defence	10.8 (5)	20.0 (7)	2.6 (1)	3.7 (1)	14.3 (11)	51.4 (4)
57 Security & investigation, etc.	1.5 (0.7)	1.5 (0.5)	0.0 (0.0)	22.2 (7)	0.3 (0.2)	25.5 (2)
24 Furniture; other manufacturing	0.4 (0.2)	1.0 (0.3)	8.1 (3)	5.0 (1)	6.6 (5)	21.1 (2)
Other sectors	12.5 (6)	8.6 (3)	6.0 (2)	22.5 (7)	12.1 (9)	61.7 (5)
Total	**194.6 (100)**	**278.8 (100)**	**254.5 (100)**	**337.1 (100)**	**129.7 (100)**	**1194.7 (100)**

We then used these sector shares by programme to disaggregate projections of total ESA programme spending in the UK over 2020-25 by sector, which we took from the UK entries in the contributors' financial obligations dataset. The outcome of this procedure was a disaggregated projection of total programme spend by sector over the 2020-25 period for each programme. With this method, we have effectively assumed that the sectoral split within each programme does not change over the projection period.

It is also worth noting that ESA spending over 2020-25 is likely to be increasingly funded by CMIN19 as time goes by and the CMIN16 funding is used up. In using the data covering 2016-2021Q2 to estimate sectoral shares of the period 2020-25, and given the geo-returns dataset does not distinguish between CMIN16- and CMIN19-funded contracts, we are thus also

implicitly assuming that there is no fundamental difference in sectoral structure of spending between the different CMINs.

We made two additional adjustments to the financial obligations data. Firstly, we filtered out some spending data to ensure that the modelled spending is for the programme activities covered under the scope of this evaluation:

- From the "Mandatory activities and science programme", we used only the "Science programme" spending.
- From the "Launch" programme, we used only spending from the "Crew Space Transportation System" project, excluding the "Space Rider PRIDE" programme.

Secondly, the spending projections were adjusted by subtracting the overhead for each programme on the ESA basis (equivalent overhead rate on a UKSA basis in parenthesis). The overhead rates for each programme are as follows:

- Earth Observation: 15% (17.6%)
- Exploration: 16% (19%)
- Science: 20% (25%)
- Telecommunications: 20% (25%)
- Navigation: 15% (17.6%)
- Space Safety: 16% (19%)
- Launch: 10% (11.1%)
- Technology: 20% (25%)

Figure 1 summarises the adjusted contributors' financial obligations data, showing the total projected spend under the four main programme headings (with an aggregate figure for the other programmes) over 2020-2025. It shows that spending across most of the programmes is due to decrease by around 50% over this period, with the exception being the Science programme, where spending is projected to be stable.

Figure 1 Geo-returns contract value by programme and SIC code (2-digit), 2016-21

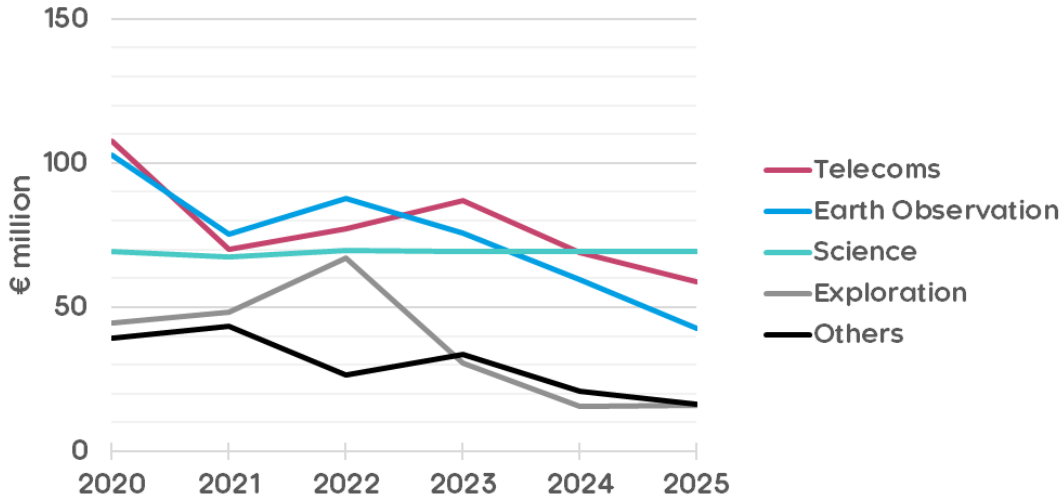

Table 2 shows the projected spend across the top ten sectors (for all programmes combined) over the study period. The sectoral shares differ slightly from the shares in Table 1 because of compositional effects from changes in the relative size of the programmes over time (as is visible

in Figure 1). However, these compositional changes are relatively small, so the sectoral splits in Table 2 broadly follow the same pattern as in Table 1, with a concentration of spending in the same five key sectors.

Table 2 Spending projections by programme, 2020-25

€ millions (% of programme total)	2020	2021	2022	2023	2024	2025
23 Other transport equipment	97.5	85.0	104.6	74.2	54.1	46.2
	(27)	(28)	(32)	(25)	(23)	(23)
19 Computer, optical & electronic	56.7	46.0	50.0	48.8	43.5	39.2
	(16)	(15)	(15)	(16)	(19)	(19)
42 Telecommunications	47.7	33.1	35.9	38.1	30.2	25.1
	(13)	(11)	(11)	(13)	(13)	(12)
51 R&D	35.4	29.2	32.3	28.9	24.1	21.3
	(10)	(10)	(10)	(10)	(10)	(10)
50 Architectural & engineering	29.4	26.1	24.6	24.6	19.5	16.9
	(8)	(9)	(8)	(8)	(8)	(8)
43 Computer programming, info services	23.4	17.3	19.5	18.7	15.3	13.0
	(6)	(6)	(6)	(6)	(7)	(6)
53 Other professional	22.9	23.3	18.9	20.4	15.0	13.0
	(6)	(8)	(6)	(7)	(6)	(6)
58 Public administration & defence	17.3	16.5	14.9	14.9	11.5	9.7
	(5)	(5)	(5)	(5)	(5)	(5)
57 Security & investigation, etc.	8.2	5.5	6.1	6.7	5.4	4.6
	(2)	(2)	(2)	(2)	(2)	(2)
24 Furniture; other manufacturing	5.7	4.8	5.0	4.2	3.0	2.5
	(2)	(2)	(2)	(1)	(1)	(1)
Other sectors	19.4	17.4	16.5	16.8	13.2	11.6
	(5)	(6)	(5)	(6)	(6)	(6)
Total	**363.6**	**308.7**	**285.1**	**284.6**	**225.4**	**195.2**
	(100)	**(100)**	**(100)**	**(100)**	**(100)**	**(100)**

F.2 ESA-derived activities

The modelling of effects emerging from ESA-derived activities was fully based on primary data collection provided via the ESA contractors survey. It is based on 5 questions:

Table 3 Survey questions use to inform estimates of economic impact

Category	Question
Prior contracts	**Did your company secure any ESA contracts under the programme before 2020?**
Total Value of contracts (£m)	**With regards to your ESA contract(s) under the programme....** What is their total value to your organisation (£m): • In the period 2018-2019 (2 full calendar years) • In the period 2020-2021 (2 full calendar years)
Total Income generated by these capabilities /products / services (£m)	**Thinking of the outputs of your ESA contracts (new and improved capabilities, products /services commercialised); what follow-on sales do they support?** **Income generated** by these capabilities /products / services (£m): • In the period 2018-2019 (2 full calendar years) • In the period 2020-2021 (2 full calendar years) • Expected from 2022 onwards
Time for effects to materialise (in years)	**Thinking about the benefits generated by UK investment in ESA, what is your view on the typical timescales to the start of benefits and the duration of benefits?** Time between start of ESA contract and start of benefit (in years): • Follow-on sales based on new products/ services/ capabilities
Duration of effects (in years)	**Thinking about the benefits generated by UK investment in ESA, what is your view on the typical timescales to the start of benefits and the duration of benefits?** Duration of benefit (in years): • Follow-on sales based on new products/ services/ capabilities

The information provided in the ESA contractor survey was then modelled to produce estimates of impact, as follows:

Value	As provided via survey	Additional calculations

Cumulative - Based on data (on contracts & income) from companies that have contracts either in 2018-2019 or 2020-2021 (or both periods)

	Values		Number of obser-vations	Notes
Total Value of contracts (£m)				
[1] In period 2018-2019 (2 full years)	82.3		36	
[2] In period 2020-2021 (2 full years)	104.9		72	
[3]Total 2018-2021	187.2			
Total Income generated by these capabilities /products / services (£m)				
[4] In period 2018-2019 (2 full years)	48.2			
[5] In period 2020-2021 (2 full years)	98.0		64	
[6] Expected from 2022 onwards	8358.3		70	
[7] Expected from 2022 onwards (excl. outliers)	1158.3		66	Excludes 4 outliers (with value higher than 1 standard deviation + mean) (*)
Total income per value of contract				
[8] From 2018 onwards	45.4	[4+5+6]/[3]		
[9] From 2018 onwards (excl. outliers)	7.0	[4+5+7]/[3]		
[10] (Mean) Time for effects to materialise (in years)	2.9		51	Based on all companies that provided information
[11] (Mean) Duration of effects (in years)	11.5		44	Based on all companies that provided information

* Outliers were identified as those with an estimated expected income that was 1 standard deviations of the mean. The outliers excluded provided estimates that are 9-10 times of the ones presented in the table. The study team take the view that the values provided are not robust (and may even been provided mistakenly). As such they have not been carried forward to produce ranges or sensitivity analysis.

Table 4 ESA-derived activities – Estimates of economic impact (1)

Estimates	Value	Notes
Additional (net) income, per £	7.0	As presented in row [8]
Additionality score	0.7	Measured in answer to response of the extent to which benefits could not have occurred without the ESA contracts.
Additional (net) income, after acounting for deadweight, per £	4.9	Obtained after applying additionality score
Additional (net) GVA, per £	**2.5**	After applying a GVA/income ration of 1:51.1 based on the weight average of GVA/income obtained from the CE modelling

As explained in the Main report, the figures above are based on the additional income reported by all organisations, including those that have contracts in 2018-2019 (for a given programme), i.e., prior to CMIN19, and are aggregated this way to take into account that ESA contracts offer, in many cases, opportunities to make incremental changes to existing technologies / solutions and that benefits accrue overtime (and often as a result of consecutive contracts). This group also offer a larger pool of responses to draw from.

To further isolate the effect of CMIN19 contracts we focus only on organisations that have had contracts in 2020-2021, but not prior to 2020 (for a given programme). For these 'new entrants' we estimate that their ESA contracts (and resulting new capabilities, products and / or services) will deliver a total additional income of £10.6m, in 2020-2021, with a further £355.3m expected from 2022 and onwards. Compared to the value of their contracts in 2020-2021, this would mean that **each £1m in value of ESA contracts generates £8.1m in *net* additional income** for those organisations (i.e., after accounting for additionality). This higher return on investment might be explained by the fact that these new entrants exclude well-stablished, big operators (such as Airbus and Thales) whose major developments will probably lead to further sales or contracts to institutional buyers like ESA, while new entrants are likely to operate in other commercial markets, with larger (expected) opportunities for follow-on sales.

However, given the relatively small sample in which these results are based, the study team has taken the view that the estimates based on all the organisations surveyed are more reliable.

Value	As provided via survey	Additional calculations

Based on data (on contracts & income) from companies that did not have contracts in 2018-2019 (to isolate effects)

	Values		Number of observations	Notes
Total Value of contracts (£m)				
[1] In period 2020-2021 (2 full years)	30.0		35	
Total Income generated by these capabilities /products / services (£m)				
[2] In period 2020-2021 (2 full years)	10.6		26	
[3] Expected from 2022 onwards	1355.3		32	
[4] Expected from 2022 onwards (excl. outliers)	355.3		31	excludes 1 outlier (with value higher than 1 standard deviation + mean)
Total Income per value of contract				
[5] From 2020 onwards	45.6	[2+3]/[1]		With focus on effects 2022 onwards given time lags
[6] From 2020 onwards (excl. outliers)	12.2	[2+4]/[1]		With focus on effects 2022 onwards given time lags
[7] (Mean) Time for effects to materialise (in years)	2.9		51	Based on all companies that provided information
[8] (Mean) Duration of effects (in years)	11.5		44	Based on all companies that provided information

Table 5 ESA-derived activities – Estimates of economic impact (2)

Estimates	Value	Notes
Additional (net) income, per £	12.2	As presented in row [8]
Additionality score	0.7	Measured in answer to response of the extent to which benefits could not have occurred without the ESA contracts.
Additional (net) income, after accounting for deadweight, per £	8.1	Obtained after applying additionality score
Additional (net) GVA, per £	**4.1**	After applying a GVA/income ration of 1:51.1 based on the weight average of GVA/income obtained from the CE modelling

Appendix G Additional education and outreach data

G.1 Sources of funding for UK education and outreach activities

Table 6 Budget for UK Space Agency outreach activities for 2021/22

2021/22 budget	£	%
ESA funding for ESERO activities	159,483	19%
UKSA funding for ESERO activities	251,000	31%
UKSA funding for national (non-ESERO) outreach activities	412,000	50%
Total	**822,483**	**100%**

Technopolis (2021)/ UK Space Agency data (Education and Skills Team)

G.2 HESA Data Group Classifications used for the three groups of HE courses

The table below presents the HESA codes and domains used in each of the three groups used in the analysis. HESA coding system changed in 2019 and therefore the codes for both periods are shown along with HESA's mapping of the codes between the two coding systems.

Table 7 HESA codes for the groups 1 and 2

Group	JACS3 code	JACS3 Label (2014/15 – 2018/19)	Relation to HECoS Label	HECoS code	HECoS Label (2019/20)
Group 1 – Space Specific Courses	F520	Space & planetary sciences	Related match	101102	Space science
	F521	Space science	Close match		
	F520	Space & planetary sciences	Related match	101103	Planetary science
	F522	Planetary science	Close match		
	F530	Solar & solar terrestrial physics	Related match		
	F540	Astronomy observation	Related match	100414	Astronomy
	H420	Astronautical engineering	Close match	100116	Space technology
	H643	Satellite engineering	Close match	100118	Satellite engineering
Group 2 – Space Related Courses	H440	Aerodynamics	Close match	100428	Aerodynamics
	H410	Aeronautical engineering	Close match		
	H441	Flight mechanics	Related match	100114	Aeronautical engineering
	H400	Aerospace engineering	Close match		
	H490	Aerospace engineering not elsewhere classified	Related match	100115	Aerospace engineering
	H450	Propulsion systems	Close match	100564	Aerospace propulsion systems
	F500	Astronomy	Close match		
	F550	Astronomy theory	Related match		
	F590	Astronomy not elsewhere classified	Related match	100414	Astronomy
	F510	Astrophysics	Close match	100415	Astrophysics

	F762	Large-scale atmospheric dynamics & transport	Related match	101068	Atmospheric physics
	H460	Aviation studies	Close match	100229	Aviation studies
	H430	Avionics	Close match	100117	Avionics
	F764	Climate & climate change	Close match	101070	Climate change
	F760	Climatology	Close match	100379	Climate science
	H441	Flight mechanics	Related match	100430	Mechanics
	F761	Meteorology	Close match		
	F763	Boundary-layer meteorology	Related match	100382	Meteorology
	F732	Oceanographic survey & monitoring	Related match	100421	Ocean sciences
	F732	Oceanographic survey & monitoring	Related match	100219	Surveying
	F765	Radiative processes & effects	Related match	101074	Radiation physics
	F845	Remote sensing	Close match	101056	Remote sensing

HESA

G.3 University departments that offer space-related courses

The table below presents the members of the Space Universities Network (SUN) – a network of university departments that provide teaching and learning in space subjects.

Table 8 SUN members

Institution	Department
Birkbeck University of London	Earth and Planetary Sciences
Brunel University London	Mechanical and Aerospace Engineering
Cardiff University	Physics and Astronomy
City, University of London	Mechanical Engineering and Aeronautics
City, University of London	Electronic & Radio Engineering
City, University of London	London Space Innovation Centre
Cranfield University	Engineering
Cranfield University	Aerospace Engineering
Edge Hill University	Computer Science
Edge Hill University	Geography
Imperial College London	Aerospace Engineering
Imperial College London	Earth Science and Engineering
Kingston University, London	Aerospace Engineering
Kingston University, London	Science, Engineering and Computing
Open University	Physical Sciences
Open University	Planetary and Space Sciences
Queen Mary College	Aerospace Engineering

UCL Mullard Space Science Laboratory	Space and Climate Physics
UCL Mullard Space Science Laboratory	Systems engineering
Ulster University	Computer Science Research Institute
University of Glasgow	Engineering (Systems, Power and Energy)
University of Oxford	Planetary exploration
University College London	Space Domain
University College London	Space and Climate Physics
University of Bath	Electronic and Electrical Engineering
University of Birmingham	Engineering
University of Birmingham	Metallurgy & Materials
University of Birmingham	Space Environment and Radio Engineering (SERENE) Group
University of Bradford	Biomedical and Electronics Engineering
University of Bristol	Aerospace Engineering
University of Cambridge	Department of Geography
University of Edinburgh	Physical & Astronomy
University of Edinburgh	Engineering
University of Glasgow	Astronomy and Astrophysics
University of Glasgow	Engineering (Systems, Power and Energy)
University of Hertfordshire	Aeronautics and Space Division
University of Leicester	Physics and Astronomy
University of Lincoln	Robotic Engineering and Control
University of Liverpool	Engineering
University of Liverpool	Aerospace Engineering
University of Manchester	Aerospace Engineering
University of Manchester	Planetary Science
University of Manchester	Earth and environmental Sciences
University of Nottingham	Engineering
University of Nottingham	Mechanical, Materials and Manufacturing Engineering
University of Oxford	Astrophysics
University of Oxford	Physics
University of Oxford	Atmospheric and Space Physics
University of Reading	Electronic Engineering
University of Salford	Aerospace Engineering
University of Sheffield	Control and Systems Engineering
University of Sheffield	Maths
University of South Wales	Computing, Engineering and Science
University of Southampton	Aerospace Engineering
University of Southampton	Astronautics Engineering
University of Strathclyde	Mechanical and Aerospace Engineering

University of Strathclyde	Strathclyde Space Institute
University of Surrey	Surrey Space Centre
University of Warwick	School of Engineering
University of West of England	Engineering, Design and Maths
University of West of England	Aerospace Engineering
Wrexham Glyndwr University	Applied Science, Computing and Engineering

Space Universities Network. https://www.spaceuniversitiesnetwork.ac.uk/

Appendix H UK committee membership

The table below provides a list UK membership of space committees and boards as of Q4 2021.

No.	Programme / domain	Name	Job title/ employment position	Current organisation	Committee / Board role	Committee	Committee role (detail)	Total number of committee members
1	Science HRE EO	Prof. Chris Rapley	Professor of Climate Science	University College London	Chair	European Space Sciences Committee (ESSC)	Chair of European Space Sciences Committee (ESSC) (The overarching chair above the four panels)	1
2	EO	Dr. Michaela Hegglin	Associate Professor of Atmospheric Chemistry in the Meteorology Department	University of Reading	Member	European Space Sciences Committee (ESSC)	Member of ESSC Panel on Earth Sciences	6
3	Science HRE	Prof. Kai Bongs	Director of innovation for the College of Engineering & Physical Sciences, School of Physics and Astronomy	University of Birmingham	Member	European Space Sciences Committee (ESSC)	Member of ESSC Panel on Life and Physical Sciences	8
4	Science HRE	Prof. Mahesh Anand	Professor of Planetary Science and Exploration	The Open University	Chair	European Space Sciences Committee (ESSC)	Chair of the ESSC Panel on the Solar System and Exploration	7
5	Science	Prof. Matt Griffin	Head of the Astronomy Instrumentation Group, Cardiff Hub for Astrophysics Research & Technology, School of Physics & Astronomy	Cardiff University	Member	ESA Space Science Advisory Committee (SSAC)	Member of ESA SSAC 2021-2023	12
6	Science	Prof. Jonathan Rae	Professor, Department: Mathematics, Physics and Electrical Engineering	Northumbria University	Member	ESA Space Science Advisory Committee (SSAC)	Member of ESA SSAC 2021-2023	12
7	Science	Prof. Clare E. J. Watt	Professor, Department: Mathematics, Physics and Electrical Engineering	Northumbria University	Member	ESA Space Science Advisory Committee (SSAC)	Ex-officio member of ESA SSAC - due to being Chair of PSWG	n/a
8	Science	Prof. Chris Rapley	Professor of Climate Science	University College London	Member	ESA Space Science Advisory Committee (SSAC)	Ex-officio member of ESA SSAC - due to being Chair of ESSC	n/a
9	Science	Prof. Tim Naylor	Norman Lockyer Professor of Astrophysics, School of Physics	University of Exeter	Member	ESA Astronomy Working Group (AWG)	Member of ESA AWG 2020-2022	12
10	Science HRE	Prof. Geraint Jones	Professor of Planetary Science, Head of Mullard Space Science Laboratory Planetary Science Group	University College London	Member	ESA Solar System and Exploration Working Group (SSEWG)	Member of ESA SSEWG 2022-2024	12

11	Science HRE	Dr Manish Patel	Senior Lecturer (Research) in Planetary Sciences, Faculty of Science, Technology, Engineering & Mathematics	The Open University	Member	ESA Solar System and Exploration Working Group (SSEWG)	Member of ESA SSEWG 2021-2023	12
12	HRE	Prof. Anu Ojha	A director of the National Space Centre and on the Council of the STFC	National Space Centre	Member	ESA Human Spaceflight and Exploration Science Advisory Committee (HESAC)	Member ESA HESAC Jan 2018 - Dec 2021	10
13	HRE	Prof. Sir. Munir Pirmohamed	David Weatherall Chair of Medicine	University of Liverpool	Member	ESA Human Spaceflight & Exploration Science Advisory Committee (HESAC)	Member ESA HESAC Jan 2018 - Dec 2021	10
14	HRE	Prof. Caroline Smith	Head of Earth Sciences Collections and Principal Curator of Meteorites	Natural History Museum	Member	ESA Human Spaceflight and Exploration Science Advisory Committee (HESAC)	Member ESA HESAC Jan 2018 - Dec 2021	10
15	EO	Prof. Jacqueline McGlade	Professor of Natural Prosperity, Sustainable Development and Knowledge Systems	University College London	Member	ESA Advisory Committee for Earth Observation (ACEO)		13
16	EO	Prof. Andrew Watson	Royal Society Research Professor, Heads of the Marine and Atmospheric Science group	University of Exeter	Member	ESA Advisory Committee for Earth Observation (ACEO)		13
17	Science	Dr Chris Arridge	Reader, Department of Physics	University of Lancaster	Co-Chair	ESA Voyage 2050 Senior Committee		13
18	Science	Prof. Mike Cruise	Honorary Professor of Astrophysics and Space Research	University of Birmingham	Member	ESA Voyage 2050 Senior Committee (and former chair of ESA Human Exploration Advisory Committee, HESAC)	Member of ESA Voyage 2050 Senior Committee (as Chair of Topical Team 5)	13
19	Science	Pro. Richard Harrison	Head of Space Physics Division and Chief Scientist	Rutherford Appleton Laboratory (RAL Space)	Member	Voyage 2050 -Topical Team 1: Solar and Space Plasma Physics		12
20	Science	Prof. Ineke De Moortel	Professor, School of Mathematics and Statistics	University of St Andrews	Member	Voyage 2050 -Topical Team 1: Solar and Space Plasma Physics		12
21	Science	Prof. Lyndsay Fletcher	Professor of Astrophysics	University of Glasgow	Member	Voyage 2050 -Topical Team 1: Solar and Space Plasma Physics		12
22	Science	Dr. Feargus Abernethy	Senior Spaceflight Project Officer	The Open University	Member	Voyage 2050 -Topical Team 2: Planetary Science		15

23	Science	Dr. Mohamed Ramy El-Maarry	Lecturer Planetary Sciences	Birkbeck, University of London	Member	Voyage 2050 -Topical Team 2: Planetary Science		15
24	Science	Prof. Simon F. Green	Professor of Planetary and Space Science, Faculty of Science, Technology, Engineering & Mathematics	The Open University	Member	Voyage 2050 -Topical Team 2: Planetary Science		15
25	Science	Dr. Davide Gerosa	Lecturer, School of Physics and Astronomy	University of Birmingham	Member	Voyage 2050 -Topical Team 4: The Extreme Universe, including Gravitational Waves, black holes, and compact objects		10
26	Science	Prof. Mike Cruise	Honorary Professor of Astrophysics and Space Research	University of Birmingham	Co-Chair	Voyage 2050 -Topical Team 5: Cosmology, Astroparticle Physics and Fundamental Physics		10
27	Science	Prof. Claudia de Rham	Professor of Theoretical Physics	Imperial College	Member	Voyage 2050 -Topical Team 5: Cosmology, Astroparticle Physics and Fundamental Physics		10
28	Science	Prof. Thomas Sotiriou	Professor of Gravitational Physics, Director of Research, Faculty of Science	University of Nottingham	Member	Voyage 2050 -Topical Team 5: Cosmology, Astroparticle Physics and Fundamental Physics		10
29	EO	Prof. Jadunandan Dash	Professor in Remote Sensing within Geography and Environmental Science	University of Southampton	Vice-chair	COSPAR Scientific Commission A: Space Studies of the Earth's Surface, Meteorology, and Climate: Task Group on GEO		(17 at least in sub-commission)
30	EO	Prof. Jadunandan Dash	Professor in Remote Sensing within Geography and Environmental Science	University of Southampton	Vice-chair	COSPAR Scientific Commission A: Sub-Commission A3: Land Processes and Morphology	Vice-chair of a Sub-Commission A3, COSPAR, 2018-2022	(17 at least in sub-commission)
31	HRE	Prof. Ian Crawford	Professor of Planetary Science & Astrobiology, Department of Earth and Planetary Sciences	Birkbeck College, University of London	Chair	COSPAR Scientific Commission B: Space Studies of the Earth-Moon System, Planets, and Small Bodies of the Solar System: Sub-Commission B3: The Moon	Chair of sub-commission B, COSPAR, 2021-2024	
32	HRE	Dr. Colin Wilson	Atmospheric Physics Clarendon Laboratory	University of Oxford (recently moved to ESTEC but still affiliated with Oxford)	Vice-chair	COSPAR Scientific Commission B: Space Studies of the Earth-Moon System, Planets, and Small Bodies of the Solar System: Sub-Commission B4: Terrestrial Planets	Vice-chair of Sub-Commission B4: Terrestrial Planets	

33	HRE	Dr. Adam Masters	Space and planetary scientist with the Space & Atmospheric Physics Group at Imperial	Imperial College	Vice-chair	COSPAR Scientific Commission B: Space Studies of the Earth-Moon System, Planets, and Small Bodies of the Solar System: Sub-Commission B5: Outer Planets and Satellites	Vice-chair of Sub-Commission B5: Outer Planets and Satellites	at least 23
34	Technology	Katharina Brinkert	Assistant Professor in Catalysis, Department of Chemistry	University of Warwick	Vice-chair	COSPAR Scientific Commission G: Materials Sciences in Space	Vice-chair of Scientific Commission G, COSPAR (2021-2024)	at least 4
35	SSS	Prof. Karen Olsson-Francis	Professor of Geomicrobiology, Faculty of Science, Technology, Engineering & Mathematics	Open University	Member	COSPAR Panel on Planetary Protection (PPP)	Member (appointed by UKSA), 2019-2022	13
36	Skills	Dr. Diego Altimirano	Principal Research Fellow at the Astronomy Group, School of Physics and Astronomy,	University of Southampton	Vice-chair	COSPAR Panel on on Capacity Building (PCB)	Vice-chair of PCB, COSPAR, 2018-2022	at least 10
37	n/a	Prof. Malcolm MacDonald	Director of the Scottish Centre of Excellence in Satellite Applications	University of Strathclyde	Member	COSPAR Task Group on Establishing a Constellation of Small Satellites (TGCSS)	Member of TGCSS, COSPAR, 2020-2024	10
38	n/a	Prof. Jonathan Rae	Professor, Department: Mathematics, Physics and Electrical Engineering	Northumbria University	Member	COSPAR Task Group on Establishing an International Geospace Systems Program	Member of TGIGSP, COSPAR, 2021-2025	unknown