Consultation on Orbital Liabilities, Insurance, Charging and Space Sustainability – response form

Closing date: 05 January 2024

Any enquiries regarding this publication should be sent to us at spaceflightregulation@ukspaceagency.gov.uk

Introduction

In its response to the June 2022 liabilities and insurance call for evidence, the Government committed to consult on a range of issues relating to orbital liabilities and insurance. This consultation delivers on that commitment. The variable liability limit approach proposed in this consultation reflects the sustainability priorities of the National Space Strategy and the commitment in the Plan for Space Sustainability for the Government to consider ways to reduce insurance premia for satellite operations. It includes a proposal for a variable liability limit, which would implement variable liability limits for satellite missions determined by operators' implementation of measures designed to promote sustainability and promoted by the UK Government as part of its emerging sustainability agenda.

This document is a template response form to respond to this consultation.

Any decisions on proposed approaches to be adopted will be taken in light of this consultation. This may result in alternative approaches or policies to those noted or considered in this document.

Contents

General information

Why we are consulting

The Government issued the Liabilities, Insurance and Charging consultation in October 2020 covering the proposed approach to determining insurance requirements for launches licensed under the SIA 2018, the liabilities provisions contained in the draft Space Industry Regulations and associated guidance. In response to this, industry raised several matters regarding existing orbital liability and insurance policy, which the UK Government committed to reviewing.

The National Space Strategy, published in September 2021, stated the UK Government commitment to undertake a review of the key concerns and proposals raised by respondents to the consultation document entitled 'Unlocking commercial spaceflight for the UK: consultation on draft insurance and liabilities requirements to implement the Space Industry Act' ('the Liability, Insurance and Charging consultation'). The UK Government issued a call for evidence in October 2021 to gather evidence, data and information to assist in policy development on these matters.

The UK Government published its response to the call for evidence in June 2022. The Government committed to work with the sector to develop formal proposals for consultation. This consultation includes proposals to implement a variable approach to setting liability limits for in-orbit operations, the Government's latest thinking on alternative models for third-party liability insurance and a range of other issues arising from the liability and insurance review. A variable refund for orbital satellite licences to reflect sustainability aspects of a mission is also proposed.

This consultation provides an overview of policy areas which influence and could impact future adaptions to the proposed variable liability limit approach. There is a section which sets out longer-term actions that the UK could take to promote space sustainability and demonstrate leadership, including a proposal to develop a Space Sustainability Roadmap to 2050.

A supporting impact assessment has not been included with this consultation.

Whilst this consultation does not include an impact assessment, analysis has been undertaken to assess the business impacts of the proposed variable liability limit and variable refund approaches. Consultation feedback will also help inform further analysis of the benefits and costs of the proposals.

The Government has set a consultation period of 12 weeks. The Government encourages consultees to provide their responses to each section by the following deadlines:

1. **section one**: setting liability limits for orbital operations, alternative insurance models and other policy proposals – comments by 26 October.
2. **section two**: policy overview of areas influencing the proposed variable liability limit approach – comments by 7 December.
3. **section three**: longer-term UK priorities for space sustainability – comments by 7 December.

Supporting plenary sessions will be held in September 2023 for section one and early November 2023 for sections two and three. Both plenary sessions will be hosted online.

The first plenary session, covering section one of the consultation, will give an overview of the variable liability limit approach for satellite operations, set out the Government's latest thinking on the alternative insurance models, and proposals on other liability aspects covered in the liability and insurance review, and will also cover the proposed approach to charging for application fees for satellite operations licences.

The second plenary session, covering sections two and three of the consultation, will focus on space sustainability and will include the development of sustainability principles, and the outcome of two studies on propulsion and disposal.

How to respond

Issued: 14 September 2023

When responding, please state whether you are responding as an individual or representing the views of an organisation.

Your response will be most useful if it is framed in direct response to the questions posed, though further comments and evidence are also welcome.

Respond by:

- Section one responses are encouraged by 26 October 2023
- Sections two and three by 7 December 2023

Responses and Enquiries to: spaceflightregulation@ukspaceagency.gov.uk

Postal Responses and Enquiries to:

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Consultation reference: Consultation on Orbital Liabilities, Insurance, Charging and Space Sustainability

We will publish a summary of the responses received on GOV.UK. This summary will include a list of all those who responded, but will not include personal names, addresses or other contact details.

Confidentiality and data protection

Information you provide in response to this consultation may be disclosed in accordance with UK legislation (the Freedom of Information Act 2000 and the Environmental Information Regulations 2004). Please tell us **in writing** if you want any information you provide to be treated as confidential, but please be aware that we cannot guarantee confidentiality in all circumstances. Automatic confidentiality disclaimers generated by your IT systems will not be regarded as a confidentiality request.

Please see our privacy policy, any Personal Data provided will be dealt with in accordance with the Data Protection Act 2018 and the UK GDPR. Where the legal basis for processing Personal Data provided in the course of this consultation is not that of the performance of a task carried out in the public interest or in the exercise of official authority (Public Task), it is processed for a legitimate reason in connection with that task (Legitimate Interests).

Quality assurance

This consultation has been carried out in accordance with the Government’s consultation principles.

If you have any complaints about the way this consultation has been conducted, please email: bru@energysecurity.gov.uk

General questions about you

We will publish a summary of the responses received on GOV.UK. Information you provide in response to this consultation may be disclosed in accordance with UK legislation. Please see page 5 for further information on confidentiality and data protection.

If you wish your response to be treated as given in confidence, please indicate below.

I wish the information given in my response to be treated as given in confidence: **YES / NO**

Please indicate in writing if any information you provide is commercially sensitive. We will not include in the published summary any information which you indicate **in writing** is commercially sensitive, nor will data be attributed to a specific organisation (unless this has been agreed). For example, where information regarding specific types of costs as a proportion of total costs is provided, we will not include individual data sets but will give an overview of responses – for example that costs are high, medium or low.

Comment:

None of the provided information is commercially sensitive.

Your Name:

- Scarlet Banner, LLM Candidate, University of Edinburgh Law School
- Juan De Dios Montero, LLM Candidate, University of Edinburgh Law School
- Rania Amalia Djojosugito, PhD Researcher in Outer Space Law, University of Edinburgh
- Hercules Wessels, LLM Graduate, University of Edinburgh Law School
- Dr. Rachael Craufurd Smith, Reader in Law, University of Edinburgh
- Dr. Michael Picard, Lecturer in International Environmental Law, University of Edinburgh
- Dr Matthias Meng Yan Wong, Senior Tutor, Department of History, National University of Singapore
- Dr Yang Lu, Associate Professor in Computer Science, School of Science, Technology & Health, York St John University
- Dr Minkwan Kim, Associate Professor in Astronautics, Aeronautics and Astronautics Engineering Department, University of Southampton

Your Organisation (if applicable):

We do not represent any organisation but submit these comments collectively in our respective professional capacities as academics.

Address and other contact details:

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Please indicate the type of business / respondent you are from the following list:

- Business representative organisation / trade body
- Micro spaceflight-related business (up to 9 staff)
- Small spaceflight-related business (10 to 49 staff)
- Medium spaceflight-related business (50 to 250 staff)
- Large spaceflight-related business (over 250 staff)
- Insurance organisation / trade body
- Legal representative
- Academic representative
- Individual
- Charity or social enterprise
- Trade union or staff association
- Government Body
- Local government / Trading Standards
- Other regulatory body (please specify)
- Other (please describe)

If applicable, what type of licensed spaceflight activity are you considering or planning to undertake in the UK?

- Launch vehicle operator
- Vertical launch – rocket launched to orbit from a spaceport
- Air launch – rocket launched to orbit from a carrier vehicle
- Sub-orbital operator
- Balloon operator
- Satellite operator
- Satellite operator - Commercial – single satellite
- Satellite operator - Commercial – constellation
- Satellite operator - Non-commercial – single satellite
- Satellite operator - Non-commercial – constellation
- Spaceport operator
- Range control services operator

Other (if so please describe further)

- In-orbit servicing
- Debris removal

Section One

This section of the consultation sets out the Government's proposals or latest thinking on the areas covered in the Government's response to the liabilities and insurance call for evidence, which was published in June 2022. A range of matters are covered, including:

- Seeking views on the Government's proposal to adopt a variable liability limit approach for orbital operations which considers the orbital sustainability aspects of the mission.
- Setting out the Government's views on the viability of adopting alternative approaches for insuring third-party liability obligations for orbital operations;
- Referring to the development of the industry-led Space Sustainability Standard, which was announced in June 2022 as part of the UK Plan for Space Sustainability.
- Given the synergies between these three separate measures, views are sought on the overall benefits of the proposed measures in combination to potentially reduce insurance premiums and deliver other potential benefits, rather than assessing the benefits for each proposed individual measure.
- Setting out the Government's intended policy on other areas covered by the liability and insurance review to take into account the variable liability limit approach. This includes insurance requirements for end-of-life and re-entry of satellites.
- Seeking views on a possible move to a variable refund approach for orbital operations licences to align with the proposed approach to setting variable liability limits.

Relevant Annex of the Consultation on Orbital Liabilities, Insurance, Charging and Space Sustainability: Annex A – Variable Liability Limit Approach Guidance

Section One Questions:

1. Do you have any comments on the proposed two-stage approach?

Response:

i) This is an innovative approach designed to encourage sustainable practices in the space industry while at the same time seeking to ensure the UK industry remains competitive in global markets. The specific assessment of sustainability issues at stage two, alongside a generalised risk assessment in stage one, is, in particular, to be welcomed.

Although the general approach is positive, we suggest that there is a need to further clarify the concepts of 'risk' and 'sustainability' that shape the stage two analysis. At present the focus is on orbital capacity, collision avoidance, tracking, data exchange, servicing and de-orbit, all of which have important sustainability aspects alongside questions of potential liability in the case of collision, failure etc. We consider that further work is needed to articulate key sustainability dimensions relating to all four criteria, beyond the welcome inclusion of consideration of the Space Sustainability Standard and Dark and Quiet Skies under criterion one and discussion in section 10. We therefore suggest that certain aspects explored in section 7 of the consultation, such as establishing a definition of sustainability in relation to space, should be integral to developing this initial stage, not deferred as a 'longer-term' initiative.

Additional areas of consideration can and should look towards the sustainable sourcing of materials used within the entire life cycle of a space activity. This should be especially emphasized in the case of rare minerals and metals used within space activities. Efforts should be undertaken to be compliant and promote the UK's Modern Slavery Act 2015 and avoid the exploitation of vulnerable. The space industry should be mindful of where and how particular resources are collected especially when suspect of issues such as compulsory labour and slavery as described in Part 1 Section 1 of the Modern Slavery Act.

ii) The fact that the different stages of design, operation and post-mission disposal are specifically analysed is also welcome and we suggest this should be extended to also cover launch choices. Significant sustainability gains can be obtained through use of less-polluting and less-energy intensive fuels and materials. The UKSA would need to categorise and rank the major types of fuels and fuel combinations most commonly used to reward more sustainable choices. Consideration of steps being taken in other sectors, such as the shipping sector, could be informative, which recently instituted new rules to decrease problematic emissions: https://www.carbonbrief.org/analysis-how-low-sulphur-shipping-rules-are-affecting-global-warming/

In terms of orbital capacity, one guideline to follow is the ESA's Space Environment Capacity described and further developed by ESPI in this report: https://www.espi.or.at/reports/space-environment-capacity/. UKSA could factor in a similar capacity approach to encourage the use of less crowded orbits, by raising or lowering the liability limits. Transparency and Confidence Building Measures internally with the operators as well as an Environmental Impact Assessment should be required to establish risks of any operations prior and post mission, aligned with ESA's Zero Debris Charter.

iii) In order to avoid duplication and additional costs for industry, it will be essential to establish which issues are to be considered by the CAA as part of the licensing process and which under the Insurance and Sustainability review. Certain matters indicated in the stage two evaluation, such as the ability to control the satellite to avoid collision post-mission would also appear relevant from a licensing perspective. One option would be to enable the CAA to consider the Insurance and Sustainability review together with the licence application. With an integrated approach the administrative process could be streamlined for industry players, reduce wait times, and ensure that decisions are based on a comprehensive understanding of each project's risks and sustainability impacts.

2. Do you have any comments on the four criteria proposed under stage 2?

Response:

i) Clarification as to what is legally required in terms of design and operation, as opposed to being merely highly desirable, is essential to avoid either under or over-regulation. Legal standards are established both at international and domestic levels and are complex. Assistance to industry in understanding this complex regulatory environment through, for example, online resources could assist, particularly small to medium enterprises (SMEs), as well as tailored, practical training activities to prepare an application under the variable cover scheme.

Recommended Guidelines and Best Practices could be adopted to clarify aspects of design and operation, perhaps with portions that consider how the space industry outside of the UK have approached this.

ii) Consideration of conformity with recognised sustainability standards is important not just at the stage of design but also in relation to subsequent operations. 'Evidence of achieving recognition under the Space Sustainability Standard' under criterion one is extremely valuable, though the ability to select recognition under one of the specified categories outlined at section 10 could lead to rather limited and strategic engagement and may need further consideration. We understand the standard will cover all stages of the satellite life-cycle, hence its relevance at the design stage, but suggest that key standards relating to all four criteria could be identified and specifically included for evaluation under each head. The consultation notes other sustainability guidelines and standards at section 10.2 and evidence of commitment to meeting certain of these standards could provide further flexibility, particularly where a foreign operator is interested in obtaining a UK licence.

3. Do you agree that a £20m middle threshold would be an appropriate insurance requirement to reflect a value at which a minimum premium could apply?

Response:

This is a matter that is best determined by industry and the insurance community. Clarity should be given on the reasons for the middle threshold to support it as an appropriate insurance requirement.

4. For the active de-orbit method question in criterion 3, minimising risk post operations, do you have views as to what an appropriate de-orbit timeline reduction could be compared to natural decay?

Response:

Considering natural decay of orbits can take a long period of time, which leads to increased risk of collisions and space debris generation, establishing a space policy that incorporates a stringent timeline for active de-orbiting becomes more and more important. Given this understanding, we suggest that consideration be given to good or best practices in other states taking into account also the environmental implications of the different approaches. Moreover, investment in technology becomes more crucial than ever. It is important to foster technological advancements that can facilitate shorter and more environmentally friendly de-orbit timelines. This objective can be achieved through public-private partnerships or research funding, particularly in the Science, Technology, Engineering, and Mathematics (STEM) sectors.

5. Do you have any alternative suggestions for applying a variable liability limit approach?

Response:

No comment.

6. Do you believe that questions on Earth sustainability could be included in future within the scope of the proposed approach?

Response:

Yes, and as indicated above, would like to see explicit recognition of this as a relevant factor for assessment, even at this initial stage. Alongside Article IX of the 1967 Outer Space Treaty, which commits State Parties to avoid contamination of Outer Space and the environment of the Earth through the introduction of extra-terrestrial matter (which could arguably include satellite re-entry), Article III requires compliance with international law, which includes both important environmental standards and the precautionary principle, as embodied by international environmental law. Inclusion would indicate a forward looking awareness of the integrated nature of space activities and their central reliance on essential, and in some cases limited or toxic, Earth materials as a resource. Further details will be provided in our December response.

Within space discourse on Planetary Protection concerning harmful contamination, emphasis has been great on the avoidance of forward contamination (from Earth to Space). Industry must make efforts to take into consideration the consequences and ways to mediate backward contamination (from space to Earth) to the greatest extent possible.

7. Do you have any suggestions as to other topics that could be included within scope in future, for example an operator’s use of life cycle assessments as part of their mission design process (see section 2 for further background on life cycle assessment work)?

Response:

No comment.

8. Do you have any comments on possible adaptations of the proposed variable liability limit approach?

Response:

No comment.

9. What would be the impact on premiums of adopting either of these approaches?

Response:

No comment.

10. Do you have a preference for either approach and if so, why? Do you have a preference for either approach and if so, why?

Response:

No comment.

11. Do you consider that there is sufficient demand for both of these approaches to operate?

Response:

No comment.

12. If you support a collective policy approach, do you think that a single policy could be put in place to cover all UK licensed operators or should multiple policies be put in place to cover specific mission types or orbits, for example?

Response:

No comment.

13. For a collective policy approach, which industry body do you think could act as the policyholder?

Response:

No comment.

14. If either or both of these approaches were to be implemented, what would be the impacts on premiums for UK operators not covered and market capacity for the residual TPL market?

Response:

No comment.

15. Do you think that either of these approaches could offer greater benefits than those that could be achieved by reducing the liability limit only?

Response:

No comment.

16. Do you have views on how the Government should consider the viability of these alternative insurance models and how they comply with legislative and license conditions?

Response:

No comment.

17. Would the industry require any additional organisational support from Government to develop the alternative insurance model?

Response:

No comment.

18. Do you agree with the recommendation that a government space bond is not a viable option for this purpose?

Response:

No comment.

19. If you consider that it is a viable option, would you propose any changes to the approach set out?

Response:

No comment.

Responses requested regarding the analysis of implementing the proposed variable liability limit approach, possible alternative insurance models and links to the Space Sustainability Standard.

Relevant Annex of the Consultation on Orbital Liabilities, Insurance, Charging and Space Sustainability: Annex B – Proposed Variable Liability Limit and Fees Analysis

20. Please provide any views on the extent of potential benefits that could arise from the adoption of these measures either individually or in combination. If you do not consider that there would be any benefits from adopting any or all of these measures, please state your reasons why.

Response:

No comment.

Responses requested regarding other TPL and insurance matters from the liability and insurance review.

21. Do you have any comments on the proposed approach to end-of-life insurance requirements?

Response:

No comment.

22. Do you have any comments on the proposed approach to re-entry insurance?

Response:

No comment.

23. Do you have any comments on the proposed approach to existing waivers and circumstances where new waivers could be applied?

Response:

No comment.

24. What opportunities are there to develop insurance products to cover other aspects of space activities (for example business interruption insurance)?

Response:

No comment.

25. Which of these would you consider would fall to the insurance sector and which to Government to progress, were they to be adopted?

Response:

No comment.

26. How could uptake of TPL and other types of insurance be encouraged in other jurisdictions to provide opportunity for growth in the London insurance market (for example linking insurance provision to responsible behaviours or enabling access to markets if insurance is taken out)?

Response:

No comment.

27. What issues are facing insurers in terms of risk arising from increasing orbital congestion now and in the next 5-10 years?

Response:

No comment.

28. How do you think these issues could be mitigated?

Response:

No comment.

29. How do you think these issues could be mitigated?

Response:

No comment.

30. How can the limited space insurance capacity be better managed to meet the increasing demands for launch services and operations, for example an option for a single insurance requirement when multiple UK satellites are onboard the same launch vehicle?

Response:

No comment.

31. With the advent of novel technology and activities, what do you see as the key challenges and how can these be overcome? For example, is there a need to move to a product liability basis as adoption of automated collision avoidance manoeuvre systems become more prevalent.

Response:

No comment.

32. Are there any other issues that you think should be considered / addressed?

Response:

No comment.

Responses requested regarding other regulatory policy proposals and consideration.

33. Do you have any comments on the proposed approach to fees set out above? In particular:

i. the principle of aligning the fees structure with the approach to setting liability limits;
ii. the proposed changes to the constellation refunds policy to reflect the revised fee structure;
iii. the proposal on new fee waivers and whether there are any additional categories that could be included;
iv. the proposal on procurement of a launch only licences.

Response:

No comment.

34. What are the potential additional benefits in adopting this approach to charging in addition to those identified?

Response:

No comment.

35. Are there any disadvantages in adopting this approach to charging?

Response:

No comment.

Section Two

Section two: responses requested regarding policy overview of issues influencing the proposed variable liability limit approach.

This section outlines the UK Government's current thinking on a number of policy areas relating to space sustainability. Some of the policies are included as suggested questions for the proposed variable liability limit approach for orbital operations. Policy developments for relevant topics will need to be considered for future adaptions to the proposed variable liability limit approach, as well as for the current set of suggested questions (for example dark and quiet skies).

Relevant Annex of the Consultation on Orbital Liabilities, Insurance, Charging and Space Sustainability: Annex C – Presentation to UN COPUOS on enabling multi-state active debris removal and in-orbit servicing missions

Section Two Questions:

36. Do you have any comments about how future policy changes to areas outlined in this section could be best reflected in future adaptions of the proposed variable liability limit approach, were it to be adopted?

Response:

No comment.

37. Do you consider that evolving positions for any of the policy areas will be particularly important for future adaptions of the proposed variable liability limit approach?

Response:

No comment.

38. The Government would welcome views from respondents on their knowledge and use of LCAs. If you do not have such knowledge, what is your current level of environmental tracking (scope 1,2 and 3 or anything extra)?

Response:

No comment.

Section Three

Section three: responses requested regarding longer-term UK Leadership on Space Sustainability.

This section seeks views on what should be the UK Government's priorities on space sustainability in the longer term, including actions to achieve these priorities to help inform longer-term planning and the development of a Space Sustainability Roadmap. Developing a UK approach to space sustainability could cover aspects such as reducing the impact of space activities on the Earth's environment, orbital, Lunar, cis-lunar environments and other planets and solar system bodies, all of which are included in this section.

Section Three Questions:

39. What international partners do you recommend the UK should work with?

Response:

There are a number of international and inter-governmental organisations that are actively working to promote a sustainable space economy. In order to support the co-ordinated development of policy and avoid a plethora of standards (which could create problems for industry and prevent a level playing field), we encourage the UK to continue with its active international engagement in this field. The UK has shown leadership within the UN and Copuos in relation to sustainability, and is a member state of the ESA, which is independently working to support sustainable space development with its Zero Debris approach and recently published Zero Debris Charter, which seek to establish manageable and measurable milestones. Both the UN, which creates scope for dialogue across political divides, and the ESA are organisations with which the UK has a long engagement, and are key venues for the development and exchange of best practice.

In addition, the UK is a signatory to the Artemis Accords, which, though focused on Lunar exploration and deep space, affirms that space activities should be conducted with due consideration of the UN Guidelines for the Long-term Sustainability of Outer Space Activities, adopted by Copuos in 2019. The Accords also emphasise the important principle of inter-operability. The signatories comprise states with established as well as developing, aspirational space industries and the Accords could thus facilitate dialogue and understanding of the sustainability implications at different points in the development cycle.

Alongside this, the UK should continue to consolidate links with trusted state partners in the space field, such as the United States, Australia and New Zealand, and partnerships with states developing their space capabilities with whom the UK can share expertise and help build sustainability into their industries from the start.

40. Do you find the UK's partnership arrangements effective?

Response:
No comment.

41. Could the UK do more, or perhaps less, in this area?

Response:
No comment.

Responses requested regarding developing a Space Sustainability Roadmap to 2050.

42. Are there other examples of sustainability initiatives or other roadmaps which you feel could inform the development of the UK Space Sustainability Roadmap?

Response:

A Space Sustainability Rating (SSR) has already been established by a consortium including MIT, Bryce Tech, the University of Texas, and the ESA. The SSR is designed to reduce the risk of space debris, on-orbit collisions, and unsustainable space operations: it consists of "a tiered scoring system that takes a series of metrics based on models previously published by agencies and academic institutes that serve to quantify and measure sustainability decisions taken by operators.[1]"

The UKSA could rely on this precedent to adopt its own sustainability rating for UK operators. The Earth Space Sustainability Initiative (ESSI) has already mapped key environmental and sustainability standards applicable across the lifecycle of a satellite and its sustainability principles could form the basis for such a system.[2]

The ESA, through its experience with the SSR and its Cleanspace initiative, could act as a partner in developing the UK's space sustainability capacities, thereby promoting consistency across ESA and UK initiatives. In particular, the ESA has developed a life cycle assessment for its own activities,[3] with guidelines designed to reduce waste and

[1] Space Sustainability Rating, Space Sustainability Rating' < Space Sustainability Rating – Promoting Sustainable Behavior of Space Actors > accessed 5 November 2023.
[2] See Earth Space Sustainability Initiative, < https://www.essi.org/ > accessed 04 January 2024.
[3] European Space Agency (ESA), 'ESA LCA Database and Handbook: Framework for Life Cycle Assessment in Space' (*ESA*, 25 January 2021) < ESA LCA Database and Handbook: Framework for Life Cycle Assessment in Space | SDG> accessed 20 November 2023.

increase recycling.[4] These include 3D printing[5] and the use of citric acid to replace nitric acid in stainless steel manufacturing.[6]

Within the UK, the Scottish Space Sustainability Roadmap establishes specific short, medium and long-term work packages and goals to promote the sustainability of Scotland's space industry to 2050.[7] The Roadmap could be a helpful resource in developing further a UK wide space sustainability policy. In particular, the Roadmap adopts a broad definition of 'sustainability', covering both in-orbit and on-earth impacts; emphasizes the importance of strategic planning, accurate data and testing (and the avoidance of 'greenwashing'); the need for financial incentives and support, particularly for SMEs, while recognizing that there may be a place for 'sticks' as well as 'carrots'; and seeks to achieve a target of net zero emissions by 2045.

Alongside these key initiatives we would like to highlight the following guidelines, some of which establish principles or standards suited to voluntary engagement, while others would arguably be better incorporated into the licensing process itself, in order to strengthen adherence.

i) Organisation for Economic Cooperation and Development (OECD) – Environmental Due Diligence in Mineral Supply Chains[8]

The OECD guidelines promote a circular economy model in the context of mineral supply chains. The circular economy is defined as closing the resource loops by transforming waste streams into secondary raw materials.[9] These guidelines stress the importance of slowing resource loops or flows, in order to retain products in the economy for extended periods.[10] In the context of satellite activities, increased durability and lifespan in space would require fewer satellites to be manufactured over time, which would scale down raw material and energy use.

Following the UN Guidelines for the Long-term Sustainability of Outer Space, a circular economy for space would mitigate space debris generation.[11] The circular economy

[4] ESA, '12.5 Substantially reduce waste generation through prevention, reduction, recycling and reuse' (ESA, 25 January 2021) < 12.5 Substantially reduce waste generation through prevention, reduction, recycling and reuse | SDG (esa.int)> accessed 20 November.

[5] ESA, '3D Printing at EAC' (*ESA*, 8 March 2018) <3D Printing at EAC | SDG (esa.int)> accessed 20 November 2023.

[6] ESA, 'Green Technology: Citric Acid for Steel Passivation' (*ESA*, 25 January 2021) <Green Technology: Citric Acid for Steel Passivation | SDG (esa.int)> accessed 20 November 2023.

[7] AstroAgency, 'Space Sustainability A Roadmap for Scotland' (*AstroAgency*, 2022) < Sustainability Roadmap for Scotland (spacescotland.org)> accessed 5 November 2023.

[8] Organisation for Economic Cooperation and Development (OECD), 'Handbook on Environmental Due Diligence in Mineral Supply Chains' (2023) OECD Publishing < https://doi.org/10.1787/cef843bf-en > accessed 10 November 2023.

[9] Ibid, 10.

[10] Ibid, 10.

[11] Committee on the Peaceful Uses of Outer Space, "Guidelines for the Long-term Sustainability of Outer Space Activities", Vienna, 20–29 June 2018, A/AC.105/2018/CRP.20,

would also reduce greenhouse gas (GHG) emissions of the space industry and contribute to achieving the Paris Agreement goals.[12] Finally, the OECD guidelines for a circular economy recommend that resource flows should be narrowed to allow for resource efficiency.[13] As technology evolves, notably with the emergence of 3-D printing, resource efficiency finds new application in the satellite manufacturing process.

The OECD guidelines identify how an operator's practices may adversely impact the environment. For example, if an area is cleared for mining, this activity could impact biodiversity, or cause pollution if waste discharge from a mine occurs.[14] Operators should follow a minimum standard of environmental protection when sourcing products on the mineral supply chain. These aspects should be considered in the life cycle assessment of space activities when rating a UK operator. For instance, if responsible practices and sourcing of materials do not occur, the UK operator could be denied a rating with the potential loss of insurance or tax advantages, We further recommend that the UKSA take the OECD Guidelines into consideration when establishing sustainability criteria in the context of licensing to ensure that space operators have followed the principle of due diligence when sourcing material containing mineral feedstock, such as batteries, solar panels and cube-sat kits.

ii) Aluminium Stewardship Initiative (ASI)[15]

Regarding the specific case of aluminium, the UKSA could closely adhere to the standards and certification model set by non-profit ASI. These standards encompass transparency, human rights, and environmental protection.[16]

The ASI sets out standards for the production and disposal of aluminium. For example, the ASI encourages operators to minimise the generation of aluminium scrap and aim for a 100% recycling or reuse scheme. The ASI also promotes mine rehabilitation to ensure that the environment is rejuvenated once mining has ceased.[17] Finally, the ASI supports responsible production and disposal of bauxite, to prevent the discharge of bauxite residue into aquatic environments.[18]

At first glance, mining waste pollution may appear to be a remote consideration for space operators. However, the resources and manufacturing chain of the space industry have

< https://www.unoosa.org/res/oosadoc/data/documents/2018/aac_1052018crp/aac_1052018crp_20_0_html/AC105_2018_CRP20E.pdf > accessed 27 December 2023.

[12] UNFCCC, "Shifting to a Circular Economy Essential to Achieving Paris Agreement Goals", UN Climate Change News, 15 April 2021, < https://unfccc.int/news/shifting-to-a-circular-economy-essential-to-achieving-paris-agreement-goals > accessed 27 December 2023.

[13] Supra OECD n.8, 10.

[14] Supra OECD n.8, 13.

[15] Aluminium Stewardship Initiative (ASI), 'ASI Performance Standard' (2023) ASI <ASI Performance Standard V3 (aluminium-stewardship.org)> accessed 13 November 2023.

[16] Ibid, 5.

[17] Ibid, 23.

[18] Ibid, 19.

notable impacts around the world.[19] Bauxite mining in Ghana plays a key role in solar panel manufacturing. It is a key ingredient of solar panel semi-conductors, which are multi-junction cells made of indium gallium phosphide. Due to the process of resource extraction, bauxite extraction poses the risk of modern slavery and environmental injustices to local communities which may be affected by the extraction process in a specific area.[20] Notably, the guidelines mention the displacement of the environment and citizens and indigenous people's rights.[21]

In response to these risks, the UK imposes transparent reporting obligations under Section 54(4) of the UK Modern Slavery Act of 2015.[22] Therefore, the UKSA should ensure that UK operators involved in the space industry adhere to the 2015 Act, currently applicable to operators with a turnover of at least 36 million, and other legal requirements as they are adopted. We recommend that they should also encourage all companies, including those who fall below this threshold, to follow international guidelines in order to obtain materials in a transparent, ethical and sustainable way and can verify the steps they have taken in this regard.

iii) OECD Guidelines for Multinational Enterprises on Responsible Business Conduct[23]

The UKSA may also refer to the OECD guidelines for responsible business conduct; this encompasses environmental and human rights protection and covers other relevant areas such as bribery and corruption.[24]

Regarding environmental protection, the guidelines discuss using the best available technology, considering scientific information, and creating contingency plans. The guidelines also recommend circular economy initiatives, encouraging materials to be maintained in the economy for as long as feasibly possible.[25]

[19] Purwins, Sebastian. "'Come What May, We Bring Those Resources to Play': Narratives, Future-making, and the Case of Bauxite Extraction at Atewa Forest, Ghana." Area (London 1969) 54.2 (2022): 233–241.

[20] Nosmot Gbadamosi, 'Ghana high court considers NGO case against bauxite mine' (2020) < https://chinadialogue.net/en/nature/ghana-high-court-considers-ngo-case-against-bauxite-mine/ > accessed 27 December 2023; Joanna Rozpedowski, 'Africa's (Modern) Slavery Problem (2020) < https://globalsecurityreview.com/africas-modern-slavery-problem/ > accessed 27 December 2023. See also Amnesty International, 'European Union: Rules for Batteries Should Cover Bauxite, Copper, Iron' (2022) < https://www.amnesty.org/en/latest/news/2022/04/european-union-rules-for-batteries-should-cover-bauxite-copper-iron/> ; Bertie Harrison-Broninski and Jayism Hanspal, 'Is corruption and slavery the cost of a mobile phone?' (2023) < https://www.landclimate.org/is-corruption-and-slavery-the-cost-of-a-mobile-phone/ > accessed online 27 December 2023.

[21] ASI Performance Standard, 25-27.

[22] UK Modern Slavery Act 2015, Part 6, Section 54, at: https://www.legislation.gov.uk/ukpga/2015/30/section/54/enacted.

[23] OECD, 'OCED Due Diligence Guidance for Responsible Business Conduct' (2023) OCED <OECD Guidelines for Multinational Enterprises on Responsible Business Conduct | READ online (oecd-ilibrary.org)> accessed 14 November 2023.

[24] Ibid.

[25] Ibid, 37.

iv) Regulation (EU) 2017/821

The European Parliament and Council laid down supply chain due diligence obligations for Union importers of tin, tantalum and tungsten, their ores, and gold (3TG) originating from conflict-affected and high-risk areas.[26]

The UK has retained part of the EU Conflict Minerals Regulation relating to EU Commission guidance. However, the UK has not retained the key provisions imposing due diligence, third-party audits, consultations and reporting obligations on importers. Instead, the UK reached with the EU a Trade and Cooperation Agreement on 24 December 2020, which refers to conflict minerals at Article 8.10 on Trade and responsible supply chain management, and makes specific reference to the OECD Due Diligence Guidance for responsible supply chains of minerals from conflict-affected and high-risk areas. Therefore, the UK Government has announced that it expects all companies importing 3TG into Northern Ireland to comply with the OECD guidance. The Conflict Minerals (Compliance) (Northern Ireland) (EU Exit) Regulations (2020) requires the largest importers into Northern Ireland of 3TG to conduct and demonstrate due diligence to ensure that their imports have been mined and processed responsibly.[27]

Further implementation through national laws would allow for harmonisation of responsible sourcing standards for space operators across the EU and the UK.

v) ESSB-HB-U-002 - ESA – Space Debris Mitigation requirements verification[28]

These guidelines recommend efficiency in spacecraft design to mitigate space debris and collisions and increased durability to withstand environmental degradation. [29] The UKSA may refer to ESSB-HB-U-002 to achieve long-term sustainability of satellite activities.

vi) European Code of Conduct for Space Debris Mitigation[30]

[26] Council Regulation (EC) 2017/821 of 17 May 2017 laying down supply chain due diligence obligations for Union importers of tin, tantalum and tungsten, their ores, and gold originating from conflict-affected areas [2017] OJ L130/1.
[27] UK Government, "The 2021 Foreign, Commonwealth & Development Office Report", presented to Parliament by the Secretary of State for Foreign, Commonwealth & Development Affairs by Command of His Majesty, December 2022, p. 28
< https://assets.publishing.service.gov.uk/media/63cea799d3bf7f3c44bcd673/human-rights-and-democracy-2021-foreign-commonwealth-development-office-report.pdf > accessed 04 January 2024,
[28] ESA, 'ESA Space Debris Mitigation Compliance Verification Guidelines' (2023) ESA <ESSB-HB-U-002 (esa.int)> accessed 13 November 2023.
[29] Ibid, 6.1.3.
[30] UNOOSA, 'European Code of Conduct for Space Debris Mitigation' (2004) UNOOSA <Microsoft Word - CoC_v1.0 [040628].doc (unoosa.org)> accessed 13 November 2023.

These voluntary regulations again stress the importance of preventing break-ups and collisions, moving decommissioned objects away from populated regions of space and limiting the objects released in everyday operations.[31] Guideline 3.2, recommends operators appoint a "space debris manager" to ensure guidelines can be implemented more effectively, tasked with enforcing the debris mitigation plan.[32] The Code also calls on operators to adopt a 'space debris mitigation plan', which identifies the risk of debris resulting from their activities, and a plan to minimize and address such risks.

vii) BSI & ISO Standards

A number of international standards already exist to accelerate the UK's transition to a circular economy in space. For instance, BSI (British Standards Institution) facilitated the development of **PAS 2080**, which is a global standard for managing infrastructure carbon and to meet World Trade Organization requirements. The framework looks at the whole value chain, aiming to reduce carbon and cost through more intelligent design, construction and use. PAS 2080 is applicable to space mission designers, satellite constructors, and material and product suppliers, as well as regulators and financiers. PAS 2080 ensures carbon is consistently and transparently quantified at key points in infrastructure delivery through data sharing along the value chain. The UKSA can rely on this global standard to increase the traceability of carbon in the UK space sector and achieve a transition to net zero.

The BSI also established **BS 8001:2017 – "Principles of the Circular Economy in Organizations"**, which highlights the critical importance of sustainable design and remanufacturing, which can mitigate space debris. The design of spacecraft should thus preclude over-heating, excessive currents, leakage and obsolescence. Quality control listings must be established to check product durability and prohibit hazardous materials. When decommissioning, space operators should endeavour to ensure the reusability or recyclability of their spacecraft via controlled re-entry. A comprehensive circular economy model includes a design for demise approach, where metals are shielded to ensure re-entry. Producer responsibility schemes could incentivise space operators to design their products with re-usability in mind or pay the cost for disposal.

ISO standard 14062 (2002) requires an Environmental Impact Assessment (EIA) for all products at any stage of production, whether raw material acquisition, manufacture, distribution, use of disposal.[33] The UKSA's adoption of ISO 14062 could help account for the impacts of the various stages of a satellite life cycle and accelerate the introduction of a Circular Economy model for space.[34]

[31] Ibid, 1.
[32] Ibid, 3.
[33] See International Organization for Standardization, "ISO/TR 14062:2002, Environmental management – Integrating environmental aspects into product design and development", at: https://www.iso.org/standard/33020.html
[34] Dallas JA and others, 'An Environmental Impact Assessment Framework for Space Resource Extraction' (2021) 57 Space Policy 101441, discussing an EIA framework for mining in space which is an example of what considerations need to be assessed for resource extraction in space.

viii) Solar Energy UK[35]

Solar Energy UK has developed minimum guidelines to adopt an Environmental, Social and Governance standard (ESG) for suppliers of solar energy. The guidelines recommend members perform due diligence checks on suppliers to ensure compliance.[36] These ideas could be extended to the solar panel suppliers for space satellites.

ix) EU – Sustainability Due Diligence[37]

Although this Directive is not yet in force, the European Commission has proposed a Directive regarding corporate sustainability due diligence. The Directive is based on the OECD due diligence guidelines.[38] Corporate entities must identify, prevent, cease, or mitigate environmental and human rights impacts.[39] SMEs are mentioned in the proportionality section of this proposal, to support a level playing field when faced with larger enterprises better able to absorb the costs of such actions.[40] Corporate entities within what the Commission class as "group 1 companies" must also ensure that their strategy is "compatible with limiting global warming to 1.5 degrees Celsius in line with the Paris Agreement".[41] The Annex also prohibits any "measurable environmental degradation", which includes water or air pollution, harmful soil change, excessive water consumption, and harmful emissions, amongst other things.[42]

This Directive will likely impact the EU space sector and although the UK is no longer a member of the EU, there could be pressure, where the UK is engaged in collaborative ventures with industry from the EU, to adopt similar standards.

Question 42 Summary

There are a wide range of environmental and sustainability standards applicable to space activities, only some of which are space-specific. Most of the space-specific, and many general, guidelines and standards establish voluntary commitments. Though standards typically cover the design and operation of satellites, with increasing attention to fuel use, more limited attention has been given to the on-earth impact of sourcing materials, manufacture, and disposal. The OECD guidelines, discussed above, demonstrate how a full supply chain assessment can be built into the evaluation process. Similarly, the ESA has been developing a life-cycle analysis that considers the whole

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[35] Kevin McCann, 'Responsible Sourcing Guidance' (*Solar Energy UK*, 2023) <Responsible Sourcing Guidance • Solar Energy UK> accessed 12 November 2023.
[36] Ibid.
[37] European Commission Proposal 2022/0051 of 23 February 2022 for a Directive of the European Parliament and of the Council on Corporate Sustainability Due diligence and amending Directive (EU) 2019/1937.
[38] Ibid, 32.
[39] Ibid, 1.
[40] Ibid, 14.
[41] Ibid, 12.
[42] European Commission proposal 2022/0051 of 23 February 2022 Annex to the proposal for a Directive of the European Parliament and of the Council on Corporate Sustainability Due Diligence and amending Directive (EU) 2019/1937, para 18.

production chain. By drawing on the work that already underpins such guidelines, backed by robust data and transparency mechanisms, the UKSA can deepen and enhance its commitment to sustainable space development.

43. Do you think it is viable to include targets for the removal of debris relating to the UK's space activities as part of the roadmap? If so:

i. please provide your suggestions for feasible targets for 2030, 2040, 2050 and beyond;
ii. please provide your thoughts on what would be a realistic size and / or type of debris that should be considered within the scope of any targets;
iii. what are the potential benefits of including such targets with regards to:

iv. impact on the space environment;

v. benefits to the UK space sector, in particular relating to the commercialisation of the UK's ADR capability?

Response:

No comment.

44. What should be the UK Government's priorities to address space sustainability?

Response:

The UK Government's priorities in relation to space sustainability should include:

1) Continuing support for research and the collection of independent data regarding sustainable space activities in order to ensure a robust empirical basis for government initiatives in the field;
2) Active engagement with relevant stakeholders, at both international and domestic levels, including with the nations and regions, international and civil society organisations, industry and academia, in order to encourage the broader take-up of innovative, sustainable practices and assist UK industry, including SMEs;
3) Clear articulation as to the trade-offs between economic and environmental considerations that stem from policy and regulatory choices, with specific reference to how the internationally recognised 'precautionary principle' has been addressed;
4) Engagement with, and where relevant application of, existing environmental and sustainability initiatives that have a terrestrial focus, to ensure coherent and joined-up policy making. This includes circular economy and climate change control initiatives.
5) Selection of specific work-packages, focusing on a range of both relatively contained and also more ambitious, longer term, sustainability objectives. The work-packages should be informed by 1 and 2 above and by a whole lifecycle approach that takes into account terrestrial as well as space-based impacts and harms. An example of such an approach is provided by the Scottish Space Sustainability Roadmap. Each initiative should identify specific measurable targets (for instance, reducing to zero the amount of waste left-behind in orbit by a specific date), thereby enabling monitoring, transparency and public accountability and sufficient financial and administrative resources should be allocated to ensure viability of the package.

6) Support for space tool development applications. Currently, space missions are gradually incorporating circular economy concepts, and the role of IT in this transition is pivotal, offering tools for global collaboration, sharing of best practices, and enhancing transparency in resource management in space activities. IT could facilitate the adoption of an online "One Stop Shop" where companies could upload their company sustainability strategy, and SMEs in particular could obtain guidance on improving their sustainable practices. This web portal would offer updated guidance on-orbit refuelling, satellite recycling etc.

Space sustainability concerns are already well articulated in international and domestic policy documents, guidelines, and in the academic literature. Of these, we highlight the following key areas for ongoing policy engagement:

i) sustainable manufacturing, design, and decommissioning, with enhanced transparency and traceability;
ii) support for sustainable space fuels and enhanced environmental impact assessments;
iii) space congestion and use, with reference to registration requirements and the impact on quiet and dark night skies.
iv) Although not unsustainable per se, disruptive radio frequencies are another issue the space sector faces. Radio frequencies may be linked to interference with the magnetic compasses of birds, calling for a preventive approach when the UKSA and Ofcom consider granting licences.[43]

We include further details on both i and ii below at 4.

3.1 Regulatory options

In pursuing these objectives, the UK has a number of regulatory options that can be used to leverage sustainability engagement and support industry to transition. These include positive incentives to encourage voluntary take-up, for instance, a reduction in insurance premiums, as proposed in the current variable liability consultation document; tax advantages, such as reliefs or business investment tax credits or eco-modulated to reward those entities that manufacture satellite parts with recycled materials; and grants or funding support through eg. green bonds, discussed below in relation to fuel use. The UK can also mandate standards, through inclusion in the licensing process, or impose an eco-tax, by way of disincentive, on certain problematic processes or activities.

The current consultation considers reliance on an insurance premium scheme that differs depending on how sustainable an operator is. One way that this could be addressed is through engagement with an accredited space sustainability rating (SSR) scheme. As indicated at 2, an SSR has already been introduced but the UK may also wish to develop a domestic scheme, informed by domestic priorities and a whole

[43] Roswitha Wiltschko et al., '*Magnetoreception in birds: the effect of radio-frequency fields*' [2015] J R Soc Interface <Magnetoreception in birds: the effect of radio-frequency fields - PMC (nih.gov)> accessed 25 November 2023.

lifecycle approach. In particular, the UKSSR could ensure that operators responsibly source their satellites' materials by increasing traceability and transparency, for example, when sourcing solar panel minerals from the Democratic Republic of Congo (DRC).[44] Internationally recognized human rights should be considered as part of the sustainability rating, which will encourage entities to practice responsible sourcing. As noted at 2 above, the OECD offers clear guidelines to ensure responsible sourcing and the UKSSR could either implement these guidelines or add to them.

The current SSR has a four-tiered system: bronze, silver, gold, and platinum.[45] It also has a bonus scheme, which does not impact the overall rating; however, it shows that an entity has gone above and beyond the standard requirements. Different aspects of the SSR also hold different weights when the overall score is being determined; this could also be implemented if the UKSA decides to use this model.[46] Some aspects, such as decommissioning, might be more challenging to rate at the moment; however, as technology develops, this will become easier to assess. A decision would need to be taken as to which SSRs are recognized for this purpose. If an operator is rated 'gold', its insurance premium would be lower than an entity with a 'silver' or 'bronze' rating.

The accredited SSR could also be linked to an 'eco-tax' imposed on companies operating within the UK space sector. Operators with a 'gold' rating would pay less tax than 'silver' rated operators, who pay less tax than 'bronze' rated operators. Eco-taxation can therefore be "eco-modulated" depending on the sustainability rating of the operator, following the French example in the textile sector.[47]

Regardless of the approach adopted, the UK needs to ensure being rated 'gold' under an accredited SSR is substantially more economically beneficial than being rated 'silver' or 'bronze'. If operators do not comply and obtain a 'bronze' or 'silver' rating, the UK would need to clarify whether there are other negative implications. Firstly, the UKSA could work with the operator to enhance the rating, which, if not achieved within a certain period, e.g., twelve months, could become a factor in future operational licensing applications.

Requiring adherence to a recognized SSR would go beyond the existing incentive proposal and the UKSA is well aware of the need to strike a balance between compliance and being a competitor within the space sector. If the UKSA is seen as too stringent, this could lead operators relocating to a different jurisdiction. However, if the UK regulatory framework is seen as too lenient, space operators may abuse the system, and environmental harm may follow. This also underlines the importance of mixed and

[44] Kai Heron, 'Confronting Eco-Apartheid' (*Notes from Below*, 21 September 2023) <Confronting Eco-Apartheid // Notes From Below> accessed 20 November 2023; Amnesty International, 'Powering Change or Business as Usual' (*Amnesty International*, 12 September 2023) <Forced evictions at industrial cobalt and copper mines in the DRC (amnesty.org)> accessed 20 November 2023.
[45] Ibid.
[46] Ibid.
[47] See Refashion's ecomodulation fee scale online: < https://refashion.fr/pro/en/eco-modulations > accessed 27 December 2023.

reliable information resources. One approach would be to encourage compliance through capacity-building and conciliation first, with operational implications very much a measure of last resort.

The UKSA also needs to ensure SMEs feel supported if a rating system is recognized/implemented, and that this is tailored to ensure a level playing field with larger operators. SMEs have previously called upon the ESA to assist them with capacity building at the risk of them moving to another state, such as the United States of America or Luxembourg.[48]

Where specific sustainability standards are introduced, the UKSA could initially implement them as voluntary for a certain amount of time, for example, two to five years depending on the standard. After this, and once entities have had sufficient time to comply, they could then become mandatory. An exception to any transition period could be if new knowledge has shown that regulations are required to prevent significant harm to human health or the environment.[49]

45. What other actions could be included in the roadmap to address space sustainability?

Response:

In Part 7.9 of the present consultation the Government acknowledges that "[e]nvironmental benefits could be derived by not disposing of satellites into the Earth's atmosphere, reducing demand for precious resources from the Earth's environment and also reducing particulate matter caused by the re-entry of space objects and emissions and other environmental impacts created through launch and manufacture of space objects on Earth". In this section we take this forward and consider what actions could be included in a roadmap to address space sustainability and support a circular economy in space, with reference to three key areas:
45.1 Satellite manufacturing
45.2 Rocket design
45.3 Sustainable fuels.

45.1. Sustainable Manufacturing

As previously discussed, the materials used to manufacture a satellite should be resourced sustainably and responsibly. For example, secondary aluminium should be used over primary production aluminium. The University of New South Wales has stated that the global demand for primary aluminium production harms the climate.[50] However, because aluminium is highly recyclable, secondary production only requires around 5%

[48] Goda Naujokaityte 'SMEs look to play a bigger part in EU space industry' (*Science Business*, 7 October 2021) <SMEs look to play a bigger part in EU space industry | Science|Business (sciencebusiness.net)> accessed 18 November 2023.
[49] Regarding the word 'significant', the International Law Commission's draft articles on transboundary harm can be applied for an appropriate definition. See Draft articles on Prevention of Transboundary Harm from Hazardous Activities with commentaries (2001) Pg 152 s4. Transboundary Harm.pdf
[50] Alison Lennon et al. 'The aluminium demand risk of terwatt photovoltaics for net zero emissions by 2050' (2020) Nature Sustainability, 357.

of the energy needed for primary production.[51] Secondary production also generates only 3-5% of the GHG emissions from the primary production of aluminium.[52] If operators were to use secondary production aluminium when creating satellites, less energy would thus be required, and fewer GHG emissions produced. This could feed in to a higher sustainability rating than for operators using primary production aluminium in satellite manufacturing. The University states that around 75% of all the aluminium produced is still in use today, meaning that recycled aluminium is durable and could likely be used in a space context without any concerns.[53]

Consideration could also be given to the use of alternative, more sustainable, materials. There is now some interest in wooden satellites. NASA and JAXA have collaborated on a project that aims to send a wooden satellite to space.[54] Magnolia wood is optimal due to its "relatively high workability, dimensional stability and overall strength".[55] If wood is a viable alternative, producing and recycling the wood is more sustainable and environmentally friendly than the metal components used in today's satellite. It is also easier to produce and trace. The potential lifespan of this satellite may also be longer than a standard satellite due to the wood not rotting in the vacuum of space.[56]

Tests confirmed that the magnolia wood could withstand the LEO atmosphere; NASA and JAXA plan to launch the first wooden satellite in 2024.[57] If successful, the UKSA could investigate it as a viable alternative to current satellite materials. Although the magnolia tree is not native to the UK, , the Southern Magnolia or Bull Bay was introduced to Britain in 1734 and is now common in warmer parts of Britain. Magnolia wood could therefore be sourced within the UK.

There are a few considerations regarding wooden satellites. Firstly, wooden satellites will likely completely burn up during re-entry, therefore, an environmentally friendly way of decommissioning satellites will still need to be researched. Secondly, the wood needs to be responsibly resourced, Sourcing wood may be less contentious than mining for resources, however, human rights abuses and environmental damage may still occur. It also appears that wooden satellites will still include some metal materials, meaning the prior discussion regarding responsible resourcing and recycling remains relevant. Over time, the space industry could loop their mineral supply chain and increase the amount of recycled materials contained within their satellite manufacturing. As scientific

[51] Ibid, 357.
[52] Ibid, 357.
[53] Ibid, 357.
[54] Kyoto University, 'KyotoU to test slats of wood aboard Japan's Kilbo platform on the ISS' (*Kyoto University*, 31 August 2021) < Space: the wooden frontier | KYOTO UNIVERSITY (kyoto-u.ac.jp) > accessed 28 November 2023.
[55] Kyoto University, 'Space test shows magnolia may be best for wooden artificial satellite LignoSat' (*Phys Org*, 16 May 2023) < Space test shows magnolia may be best for wooden artificial satellite LignoSat (phys.org) > accessed 28 November 2023.
[56] Ben Turner, 'NASA and Japan to launch world's 1st wooden satellite as soon as 2024. Why?' (*Live Science*, 14 November 2023) <NASA and Japan to launch world's 1st wooden satellite as soon as 2024. Why? | Live Science> accessed 28 November 2023.
[57] Kyoto University (n 61).

knowledge and technology develop, recyclability targets for a circular economy in space may become more achievable

45.1.2. Increasing transparency and traceability

The UN has discussed the classification and reporting of primary and secondary materials and increasing access to information[58], which is supported by the Aarhus Convention. [59] Ensuring the public and the government have access to information regarding an operator's supply chain is essential because it pressures the operator to ensure their supply chain does not abuse any environmental protection or human rights standards and increases accountability. In relation to a circular economy, the UN raises concerns regarding the lack of guidance and definition surrounding circular economy. In response, the UN has launched a "UNECE Task Force on measuring the circular economy".[60] If the UKSA aims to transition to a circular economy in space, the UKSA should consult with this task force to ensure they obtain appropriate information and expert recommendations.

45.1.3. Lifespan

Satellite lifespans are currently short and the UKSA should encourage operators to create more durable satellites. This may not be entirely feasible today but over time, the UKSA could establish the average lifespan of a UK operator's satellite and consider this when giving a sustainability rating, encouraging operators to create more durable and sustainable satellites, create less debris, and have less environmental impact.

45.1.4. Decommissioning

Currently, there are two main feasible options r when a satellite reaches its end of life: removal to the space graveyard or re-entry into Earth's atmosphere. Neither of these options is ideal. For example, re-entry has an adverse impact on the environment, and there are security concerns regarding decommissioning satellites in the space graveyard. However, as technology and scientific knowledge evolve, there may be other ways to decommission satellites more effectively, for instance through recycling of components and retrieval in line with the circular economy ethos
For example, the University of New South Wales has developed a new way of efficiently recycling solar panels.[61] Facilitating and engaging with recycling could be a key criterion for consideration in an operator's sustainability rating.

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[58] United Nations Economic Commission for Europe (UNECE), 'Traceability, transparency and data' (*UNECE*) <Traceability, Transparency and Data | UNECE> accessed 28 November 2023.

[59] The UNECE Convention on Information, Public Participation in Decision-Making, and Access to Justice in Environmental Matters (adopted 25 June 1998, entered into force 30 October 2001).

[60] UNECE Task Force on measuring the circular economy: https://unece.org/statistics/task-force-measuring-circular-economy

[61] Neil Martin, 'New environmentally friendly solar panel recycling process helps recover valuable silver' (*The University of New South Wales*, 2 July 2023) <New environmentally friendly solar panel recycling process helps recover valuable silver | UNSW Newsroom> accessed 15 November 2023.

45.1.5. Recommendations

To conclude, the UKSA should consider creating minimum standards in relation to manufacturing that producers within, and operators seeking to launch from, the UK are required to meet or work towards, depending on the standard. These could be implemented via a sustainability rating approach or through specific legislation or licensing requirements.

The applicability of pre-existing legislation to the space sector should be clarified.

The UKSA should work closely with organisations already working in the field, such as the UNECE Task Force on measuring the circular economy, to ensure they stay updated with the evolving technology and policies. Specific circular economy targets will likely emerge once technology and scientific knowledge have developed; however, to get there, the UKSA can start adopting sustainability ratings throughout the satellite's life stages.

45.2. ROCKET DESIGN AND MANUFACTURE

Expendable rockets are destroyed when they re-enter the Earth’s atmosphere, and become space debris, which pose significant hazards and require constant monitoring. Partially reusable rockets, on the other hand, save resources for other purposes. A rocket primarily consists of metal alloys, which require a considerable amount of energy to mine, transport, and forge. The production of rockets is thus highly energy-intensive. As with any product, the more times an item is used, the less demand it places on the environment and resources.

45.2.1 State of the art: new approaches to rocket manufacturing

i) Syrora’s 3D printing

Currently, 3D printing technology using heat-resistant metal alloys is being used for trial-and-error rocket development, therefore addressing the impacts that testing and trials generate.

To develop engines faster, it is important to minimize the number of parts used, which reduces the time required for engine assembly and the impact of supply chain disruptions. One way to achieve this is by changing manufacturing processes. Space companies are now switching from subtractive manufacturing processes, which involve removing material to shape a part, to **additive manufacturing processes**, which involve building up a part by adding material to it gradually.

Through 3D printing, engineers are favouring a process called **selective laser sintering to 3D-print rocket engine parts** in an additive process. Selective laser sintering allows for multiple components to be printed in-house, as one unified part, in a matter of days. When an RUD (Rapid Unscheduled Disassembly) occurs and the fault is found, engineers can create a fix using 3D modelling software, integrating highly complex parts into new rocket engines for test firing a few days later.

Skyrora (Scotland) has begun a series of full-duration tests to qualify the updated design of its 70kN engine for its first commercial orbital launch. The engines have been 3D-printed, using Skyrora's Skyprint 2 machine.[62] A collaboration with the National Manufacturing Institute of Scotland (NMIS) will qualify the machine, materials, and process of machining for Skyprint 2.

ii) Relativity Space Terran R 3-D Printed Rocket

Relativity Space, the first company to 3D print rockets and build the largest metal 3D printers in the world, revealed plans for Terran R, its reusable, 3D printed, medium-to-heavy lift orbital launch vehicle.[63]

Terran R is a customer-centric next generation launch vehicle designed to meet the needs of commercial companies and government entities sending payloads into LEO, MEO, GEO, and beyond. Terran R's architecture choices enable accelerated development and the ability to deliver a rapidly scaling launch cadence for customers. Terran R will prioritize first stage reusability, with the capability of launching 23,500kg to Low Earth Orbit (LEO) or 5,500kg to a Geosynchronous Transfer Orbit (GTO), both with downrange landing, or up to a maximum payload of 33,500kg to LEO in expendable configuration.

45.2.2 Recommendations

i) Rocket design and manufacturing process

Spacecraft should be designed bearing the entire environmental impact (in terms of CO2 eq or other more comprehensive metrics) of the lifecycle in mind, using approaches optimised for continuously improving sustainability, considering structure and component reuse, remanufacture, repair and eventual end-of-life aspects. To reduce costs, optimise efficiency, and eliminate waste, design and manufacturing processes should be integrated and fully automated, end-to-end.[64]

The Advisory Council for Aeronautics Research in Europe has put forward the key principles of "product stewardship" and "EPR" in aerospace. For non-reusable rockets, it is recommended to (i) minimise the amount and type of material used in manufacture;

[62] See Skyrora 3-D model engine, < https://www.skyrora.com/skyrora-3d-prints-and-tests-new-model-of-orbital-engine-to-prepare-for-commercial-launch/ > accessed online, 27 December 2023.
[63] See Relativity Space "Terran R: Our Reusable 3D Printed Rocket" < https://www.relativityspace.com/terran-r > accessed online, 27 December 2023.
[64] See I. Towle, C. Johnston, R. Lingwood and P.S. Grant, "The Aircraft at End-of-Life Sector: a Preliminary Study, Department of Materials, Oxford University" (2004).

(ii) reduce and eliminate the use of toxic materials; and (iii) improve traceability of substances and materials all along the product life cycle.

For re-usable rockets, the space sector should design an end-of-life process, from storage at the pre-decommissioning phase, disassembling and dismantling, to the recycling or elimination of the materials.

For the UK Government, the recommendation is to contribute to the development of new recyclability channels and technologies; (ii) support the use of recycled aeronautical materials into new aircraft manufacturing; (iii) and develop upcycling and downcycling value chains with partners.[65]

An example of a successful recovery model is the Process for Advanced Management of End-of-life Aircraft ("PAMELA"), a project initiated by Airbus and funded by the European Commission's LIFE Environment Programs (*L'Instrument Financier de l'Environnement*).[66] The PAMELA project demonstrated the possibility of recycling up to 85% of plane components. The ISO 14001 certification was awarded to the company in 2006.

An EPR scheme under the Environment Act of 2021 can be implemented, equipment and products such as the electronics system, tyres, batteries, CFC (chlorofluorocarbon) and hydraulic fluids from aircraft have to go through a controlled processing channel. Serviceable, working spares and components recovered from end-of-life aircraft will be catalogued and tracked as they are put back into the second-hand parts supply chain.

ii) Re-use of space rockets

Reusability is a major factor in reducing the environmental impact of space launches. Aside from rockets, reusable capsules should also be an important goal for the UK Space Agency. The British company, Reaction Engines Ltd., has proposed a medium-lift, reusable rocket called Skylon that uses hydrogen as fuel.

iii) Build closed-loop engines

The aerospace industry should prioritize the use of closed-loop engines such as the RD-180, RS-25, RD-181, Raptor engine, and BE-4. These engines produce less pollution than open-cycle engines with a gas generator. Furthermore, closed-loop engines typically have a higher specific impulse, which enables them to perform more efficiently using the same amount of fuel.

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65 See UK Department for Transport's document on Sustainable Aviation (URN05/1251), which can inform regulation for the space industry.

66 European Commission, LIFE Public Database, < https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE05-ENV-F-000059/process-for-advanced-management-of-end-of-life-of-aircraft > accessed 27 December 2023.

45.3 SUSTAINABLE SPACE FUELS: A LIFE CYCLE ASSESSMENT

Hereafter we identify some of the risks and impacts that space launches may have on the Earth's environment, flesh out which alternatives currently exist to replace ordinary fossil fuels for space activities, and what regulations and policies can be applied or implemented in the UK to address this issue.

45.3.1. Background

In March 2013, the UK Government published its Aviation Policy Framework[67]. At its heart is the Government's concern with how the aviation sector may contribute to its primary objective of economic growth.[68] One of its policies is "to ensure that the aviation sector makes a significant and cost-effective contribution towards reducing global emissions".[69]

Subsequently, the Government established a Jet Zero Council with the aim of delivering at least 10% sustainable aviation fuel ("SAF") in the UK fuel mix by 2030 and deliver zero emission transatlantic flight within a generation. The Council is looking at both engine technology –supporting the development of electric and hydrogen flight– and at how we can accelerate the production of SAF.

Moreover, the UK´s Department of Transport published in July 2022 a Jet Zero Strategy, establishing a Net Zero target for the aviation sector by 2050 and for all domestic flights by 2040.[70] The Strategy defines a set of policies to be implemented in the short and medium term to achieve those goals, which can be summarised as:

- System efficiencies: improving the efficiency of the existing aviation system, including airports, airspace, and the aircraft used;
- Sustainable aviation fuels: building a thriving UK sustainable aviation fuel industry, bringing UK innovations to the commercial market, supporting green jobs and the UK's fuel security;
- Zero emission flight: developing and bringing into commercial service novel forms of aircraft that offer the potential for zero carbon tailpipe emissions;

[67] UK Secretary of State for Transport, "Aviation Policy Framework" (2013) < https://www.gov.uk/government/publications/aviation-policy-framework > accessed 1 December 2023.
[68] This Framework has been expressly made applicable to space operations by the UK 2014 Review of commercial spaceplane certification and operations, Technical Report, < https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/329758/spaceplanes-tech.pdf > accessed 1 December 2023.
[69] UK Secretary of State for Transport, "Aviation Policy Framework" (2013) 10 < https://www.gov.uk/government/publications/aviation-policy-framework > accessed 1 December 2023.
[70] UK Department of Transport, "Jet Zero Strategy" (2022) < https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1095952/jet-zero-strategy.pdf > accessed 1 December 2023.

- Markets and removals: creating successful carbon markets and investing in greenhouse gas removals to compensate for residual emissions in 2050.

This recent framework shows the UK government's commitment to promote the decarbonisation of the UK aviation industry, particularly through the strengthening of alternative fuels (SAF). This scenario may find resonance in the space industry, considering that GHG emissions are one of the main environmental impacts of space launches.

45.3.2. Environmental Impacts of space launches from within the UK

The Impact Assessment ("IA") prepared as a result of the "Space Industry Regulations 2021"[71], which complements and develops the provisions established in the "Space Industry Act 2018", identified a number of environmental impacts arising from the activity related to space launches carried out, and expected to take place, in the UK. The document distinguishes between vertical and horizontal launches.

According to the study, vertical and horizontal launches produce carbon dioxide and other greenhouse gases ("GHGs"). The most detailed assessment of the potential impact to date is a 2014 technical report on commercial spaceplane certification and operations.[72]

Most rocket fuels primarily produce carbon dioxide and water when burned. The exceptions are those that use solid fuel, or kerosene when used in an air-breathing engine (when pure oxygen is used, the combustion products are simply water and CO2).[73]

Another impact identified is ozone depletion as a result of particulate matter (chlorine and alumina particles) emissions from solid and hydrocarbon fuels[74]. The primary cause of ozone loss due to rocket emissions is through solid rocket motors[75].

The launch of space tourism may harm the ozone layer, reversing progress made after the 1987 Montreal Protocol banned ozone-depleting substances.

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[71] Space Industry Regulations (2021) <https://www.legislation.gov.uk/ukia/2021/57/pdfs/ukia_20210057_en.pdf > accessed 1 December 2023.

[72] UK government review of commercial spaceplane certification and operations: technical report <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/329758/spaceplanes-tech.pdf>, as cited in Space Industry Regulations "Impact Assessment" (2021), <https://www.legislation.gov.uk/ukia/2021/57/pdfs/ukia_20210057_en.pdf> accessed 1 December 2023.

[73] Space Industry Regulations "Impact Assessment" (2021), < https://www.legislation.gov.uk/ukia/2021/57/pdfs/ukia_20210057_en.pdf > accessed 1 December 2023.

[74] World Meteorological Organization, "Scientific assessment of ozone depletion" (2002), < https://www.wmo.int/pages/prog/arep/gaw/ozone_2002/ozone_2002.html > accessed 1 December 2023.

[75] Space Industry Regulations "Impact Assessment", *supra* note 73.

Another component of rocket launches identified in the document is soot. Rockets inject huge amounts of it into the otherwise pristine upper layers of Earth atmosphere, where it could trigger possibly far-reaching changes.[76]

Solid rocket boosters also generate black carbon. Annually the amount created by around 120 space launches is equivalent to the black carbon emissions from the entire global aviation industry.[77]

45.3.3. Characterisation of common propellants used in space launching

The propellant is the chemical mixture burned to produce thrust in rockets and consists of a fuel and an oxidiser. A fuel is a substance that burns when combined with oxygen, producing gas for propulsion. An oxidiser is an agent that releases oxygen in combination with fuel. The ratio of oxidiser to fuel is called the mixture ratio. Propellants are classified according to their state - liquid, solid, or hybrid.[78]

i) Solid propellants

Solid rocket boosters are considered the most harmful form of rocket propulsion. They are usually installed on the first stage of rockets where high thrust is essential. During takeoff, these boosters produced more than 85% of the rocket's total thrust.[79]

Solid rocket boosters are typically composed of hydrochloric acid, or more specifically ammonium perchlorate, the salt of perchloric acid and ammonia, which are powerful oxidizers, and aluminium or magnesium powders. A binder holds these together, usually hydroxyl-terminated polybutadiene (known as HTPB) or polybutadiene acrylonitrile (known as PBAN). Which makes the propellant into a rubbery like mixture. This means they emit primarily aluminium oxide, soot or black carbon, CO_2, hydrogen chloride, nitrogen oxides, hydrogen and a few other trace gases.[80]

ii) Liquid propellants

For fuels in a liquid state, most petroleum-derived hydrocarbons have the potential to be used as rocket fuels- the most common of these being kerosene.

The refined kerosene mixture RP-1 has been regularly used with liquid oxygen as the propellant for rocket engines. RP-1 is basically just a highly refined jet fuel, which in itself is just a highly refined kerosene. When burnt, RP-1 will produce CO_2, water vapor, NO_x,

[76] *Ibid*.
[77] *Ibid*.
[78] Haridwar Singh and Himanshu Shekhar, *Solid Rocket Propellants: Science and Technology Challenges* (Royal Society of Chemistry 2017).
[79] J.A. Dallas, S. Raval, J.P. Alvarez Gaitan, S. Saydam, A.G. Dempster, "The environmental impact of emissions from space launches: A comprehensive review", 2020 Journal of Cleaner Production 255, 120209.
[80] R.R. Bennett, J.C. Hinshaw, M.W. Barnes, "The effects of chemical propulsion on the environment", 1992 Acta Astronautica 26:7, 531-541.

carbon soot, carbon monoxide which again mostly becomes CO_2 and a little bit of sulfur compounds.[81]

iii) Gas propellants

Hydrogen has been seen as the cleanest burning fuel. When you burn hydrogen with oxygen, you get water vapor. Another option considered is Methane, or (when burnt with liquid oxygen) methalox.[82] Three of the newest rockets coming on line in the next couple years are all running methane: SpaceX's Starship, Blue Origin's New Glenn's first stage and ULA's Vulcan first stage.

Methalox has been stated as the next most clean fuel after hydrogen, since when burnt, methane becomes CO_2 and water vapour along with NO_x as well. A rocket running on hydrogen or methane can become mostly carbon neutral if the production of the fuels is powered by a renewable energy source.[83]

<u>45.3.4. The state of the art of Sustainable Space Fuels in and outside the UK</u>

Sustainable fuels for civil and commercial aviation are generally called Sustainable Aviation Fuels ("SAF"). For the purpose of this work, when referring to renewable or sustainable fuels for space activity (also known as "green propellants"), we will address them as Sustainable Space Fuels ("SSF").

i) Skyrora's Ecosene

Ecosene is a proprietary IP-owned product of Skyrora, placed in Scotland, which converts plastic waste into high-grade kerosene fuel for use by the aviation and aerospace industries. It meets the standards required for a Jet A-1 fuel.[84] This technology, alongside existing innovative products, can provide a sustainable solution to accessing space for the small satellite market.

Ecocene feedstock is made of unrecyclable plastic, specifically, Polypropylene (PP), Polyester (PE) Polystyrene (PS) and their mixtures and analogues. Skyrora can also use metallised packaging from waste that is not usually accepted for recycling such as crisp packets, as well as plastic that has been impacted by UV rays or salt water and previously recycled plastic.

According to the product description, the production process for ecosene is designed to eliminate the formation of dioxins and furans, and reduce CO_2 emissions by 70% when compared to traditional fuel production methods, according to the company. Allegedly, the process used for the full life cycle of ecosene has significantly lowered the

[81] Ross, M.N. and Sheaffer, P.M., "Radiative forcing caused by rocket engine emissions." 2014 Earth's Future 2: 177-196.
[82] Todd Neill, Donald Judd, Eric Veith, Donald Rousar, "Practical uses of liquid methane in rocket engine applications" 2009 Acta Astronautica, 65: 5–6, 696-705.
[83] Swati Iyer "Methalox Propellant for Future Launch Vehicles: A comparative study of methalox, hydrolox and kerolox propellants for future launch vehicles" (2022) Delft University of Technology.
[84] See Skyrora Ecosene < https://www.skyrora.com/ecosene/ > accessed 27 December 2023.

greenhouse gas emissions. The amount of CO2 produced during the process is approximately 154kg per tonne less than that emitted during the production of conventional oil-derived fuels. Ecosene is a more environmentally friendly alternative to traditional fuels.[85]

This innovation caters to the need for a worldwide shift in mentality towards reducing fossil fuel consumption and plastic waste. Adopting SSF such as Ecocene is in conformity with the Nationally Determined Contributions of the UK towards the Paris Agreement goals of GHG mitigation. By providing a solution for single-use plastic waste, Ecosene also effectively decrease the production of secondary microplastics, anticipating the UK's conformity with an upcoming legally binding multilateral environmental treaty to end plastic pollution.[86]

The Ecosene technology is currently at Technology Readiness Level (TRL) 5, which means that the team has successfully proven the feasibility of the pyrolysis stage of Ecosene production. Skyrora has achieved the recycling of plastic waste to obtain kerosene, petrol, and diesel fractions. The fuel derived from this process has been validated in its relevant environment during testing of Skyrora's 3.5kN engine tests. The resultant fuel is 1-3% more efficient than kerosene and reduces CO2 emissions during launch by 45% compared to the common LOX (liquid oxygen)/RP-1 (kerosene) propellant combination. This is a significant development in the field of sustainable rocket fuel technology.[87]

ii) Orbex's Calor BioLPG

Calor will supply Orbex with its *BioLPG* solution, a clean-burning propane produced from renewable feedstocks such as plant and vegetable waste material. This reduces CO2 emissions by as much as 80% when compared to sourcing conventional, liquefied petroleum gas (LPG) from fossil sources. It is a clean-burning propane produced from renewable feedstocks such as plant and vegetable waste material.[88] The comparison was made with launchers that burn RP-1, or Rocket Propellant 1 (already referred above). The fuel is used to launch Orbex's "Prime" rocket (orbital launch).

A study by the University of Exeter found that a single Orbex Prime launch would produce up to 96 % lower emissions than a similar-sized launch vehicle powered by fossil fuels – the result of almost entirely eliminating black carbon emissions.

[85] *Ibid*.
[86] See Resolution 5/14 adopted by the United Nations Environment Assembly on 2 March 2022, "End plastic pollution: Towards an international legally binding instrument", United Nations Environment Assembly of the United Nations Environment Programme, Fifth session, 7 March 2022, Nairobi.
[87] See Skyrora Ecosene < https://www.skyrora.com/ecosene/ > accessed 27 December 2023.
[88] Orbex, "From heating homes and businesses to launching rockets: Orbex to use Calor BioLPG for Prime launch", 02 December 2021, < https://orbex.space/news/from-heating-homes-and-businesses-to-launching-rockets-orbex-to-use-calor-biolpg-for-prime-launch > accessed 27 December 2023.

According to the study by the University of Exeter, a single launch of the Orbex Prime rocket would result in total emissions of 13.8 tonnes of CO2e. This includes the direct emissions from the launch, the indirect emissions created from the production of the propellent fuels required (biopropane and liquid oxygen), and the radiative forcing (RF) effects of non-CO2 emissions at high altitude.

The Greenhouse Gas (GHG) factor[89] for BioLPG is 90 per cent lower than a fossil-based fuel such as RP-1, the highly-refined form of Kerosene typically used as rocket fuel.[90]

iii) Green Hydrogen

The ESA and France's Space Agency Plan (CNES) are working with Air Liquide, SARA, MT-Aerospace, Be.Blue, the Université de Guyane and the Université de Liège on a project known as HYGUANE ("HYdrogène GUyanais A Neutralité Environnementale") and aim to set up a pilot plant within the French Guiana Spaceport. The pilot plant will be capable of producing 130 tonnes of green hydrogen per year. This initiative seeks to significantly reduce greenhouse gas emissions at the Spaceport. The green hydrogen produced will replace "grey hydrogen" used to fuel rockets. This will lead to a reduction of several thousand tonnes of CO2 emissions.[91]

45.3.5. Policy alternatives to encourage use of SSF in the UK space industry

In the following section, we outline some regulatory techniques that the UK Government could adopt to encourage the use of SSF by operators under a licence granted by the Civil Aviation Agency, and thereby introduce a scheme that contributes to achieving the objectives set out in the 2021 Sustainable Aviation Fuels Mandate.

SSF production capacity can be limited by a number of barriers: significantly higher costs of production for SSF in comparison to conventional kerosene; limited feedstock and fuel production infrastructure; and, perceived high risks and costs to finance SFF infrastructure.

The International Civil Aviation Organization (ICAO) submitted a policy guidance document in March 2023, intended as a support reference for ICAO Member States seeking to develop SAF production or part of the SAF supply chain such as feedstock production.

[89] Clim' Foot, "What is an emission factor?", < https://www.climfoot-project.eu/en/what-emission-factor > accessed 27 December 2023.
[90] Orbex, "From heating homes and businesses to launching rockets: Orbex to use Calor BioLPG for Prime launch", 02 December 2021, < https://orbex.space/news/from-heating-homes-and-businesses-to-launching-rockets-orbex-to-use-calor-biolpg-for-prime-launch > accessed 27 December 2023.
[91] European Space Agency, "Launch goes green with Spaceport hydrogen plan", 28 June 2022, < https://www.esa.int/Enabling_Support/Space_Transportation/Europe_s_Spaceport/Launch_goes_green_with_Spaceport_hydrogen_plan > accessed 27 December 2023.

As the implementation and usage of SAF in the aviation industry seeks the same environmental objectives and faces similar challenges as the implementation of SSF in the Space Industry, it is reasonable to conclude that this guidance can be used to design a domestic regulation towards SSF in the UK.

The characteristics of effective SAF-enabling policy discussed in the document reflect what would be considered desirable for any renewable fuel policy, according to the ICAO.

i) Stop using solid rocket boosters

Since solid rocket boosters are considered the most harmful fuel used by the space industry, the UK should aim firstly to eliminate the usage of these fuels by banning their use. This could be done by modifying the Air Quality Regulations of 2020.

ii) Update existing policies in the UK to incorporate SSF

SAF mandate UK 2025: increasing demand for SSF

The Jet Zero Strategy published in July 2022 is the strategic framework that will guide the approach to net zero aviation, and the five-year delivery plan policies and regular reviews of the Strategy will ensure the UK is on the right path to meet its commitment.

One of the policies established in the Strategy is an SAF mandate, expected to come into force in 2025. The SAF mandate will impose an obligation on fuel suppliers to reduce the greenhouse gas emissions of aviation fuel by the equivalent of at least 10% SAF use by 2030.[92]

The mandate will replace the Renewable Transport Fuel Obligation scheme ("RTFO") as the operational support mechanism for SAF from 2025. A bespoke policy will allow specific SAF targets to be set, ensure the mechanism are tailored to SAF needs and better adhere to the 'polluter pays' principle. By mandating the use of SAF, the UK seeks to generate demand for SAF and create certainty for investors via long-term targets.

The proposed SAF mandate would apply to all suppliers of aviation turbine fuel in the UK aviation market. In addition to the 10% benchmark, the mandate sets parameters on what qualifies as sustainable aviation fuel: the overall carbon intensity of SAF must be 40% lower than fossil fuel-derived kerosene, based on the UK's Renewable Transportation Fuel Obligation (RTFO), with parameters that favor feedstocks with low-emission production processes.

Currently, the mandate restricts the use of fuels derived from crop-based feedstocks that compete with food production. Instead, it requires Sustainable Aviation Fuel (SAF) to be

[92] UK Department of Transport, "Jet Zero Strategy" (2022) 36 < https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1095952/jet-zero-strategy.pdf > accessed 1 December 2023.

produced from waste or residues, such as biomass, plastic waste, or waste industrial gases, or from carbon dioxide and hydrogen (known as power-to-liquid) using low-carbon electricity sources. Hydrogen feedstocks must have low carbon intensity, which is defined as nuclear and electrolytic hydrogen, biohydrogen produced from waste or residues, and RCF hydrogen. To diversify the supply of SAF, especially to increase the availability of SAF with high GHG emissions savings potential and low land use change risk, the Department of Transportation has proposed the power-to-liquid mandate. The outcome of the second consultation on this SAF mandate will determine the supply targets enforced by the power-to-liquid mandate.

The SAF mandate would become the only scheme under which fuel suppliers would be able to claim SAF use and receive a reward, in the form of a credit, in the UK. The mandate will also provide an incentive to SAF producers in the form of a tradable certificate, which will close the price gap between fossil kerosene and SAF. SAF with greater GHG savings will receive greater support, thereby incentivising the use of the most sustainable fuels and driving carbon savings.

The SAF mandate has been designed to complement domestic and international aviation decarbonisation policy and existing international commitments to aviation decarbonisation. Namely, the UK Emissions Trading System ("ETS"), and Carbon Offsetting and Reduction Scheme for International Aviation ("CORSIA").[93]

An immediate recommendation is for the UK Department of Transport to expressly include space operations within the remit of the 2025 SAF Mandate. Moreover, the SAF Mandate 2025 should present a non-exhaustive list of SSF, which shall meet the globally accepted sustainable criteria for fuels in aviation[94]. The Mandate should also set clear standards and methods for certifying the sustainability of feedstock and fuel.

Inclusion of space industry activities under the UK ETS

Carbon markets, where space operators can obtain and surrender allowances, could be established to facilitate investment in GGR (Greenhouse Gas Removal) technologies through enabling the integration of negative emissions. Carbon markets can provide a mechanism for decarbonisation to occur where it is most cost-effective and provide a useful price signal for investors.

In the UK, the ETS works on the basis of a 'cap and trade' principle, where a cap is set on the total amount of certain greenhouse gases that can be emitted by sectors covered by the scheme. This limits the total amount of carbon that can be emitted and, as it

[93] To see the timeline of the work to date and next steps: < https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1147350/pathway-to-net-zero-aviation-developing-the-uk-sustainable-aviation-fuel-mandate.pdf > accessed 27 December 2023.

[94] A set of Sustainability Criteria was approved by the ICAO Council, in the context of consideration of Sustainable Aviation Fuels and Lower Carbon Aviation Fuels under CORSIA. These Criteria are registered in the ICAO document "CORSIA sustainability criteria for CORSIA eligible fuels".

decreases over time, will make a significant contribution towards the Net Zero 2050 target and other legally binding carbon reduction commitments. Within this scheme, participants receive free allowances and/or buy emission allowances at auction or on the secondary market, which they can trade with other participants as needed.

The UK ETS applies to energy intensive industries, the power generation sector and aviation. Activities in scope of the UK ETS are listed in Schedule 1 (aviation) and Schedule 2 (installations) of the Greenhouse Gas Emissions Trading Scheme Order 2020[95]. The list does not include spaceflights or launches within the space industry, which could be included in order to foster incentives for the usage of SSF.

45.3.6. Other policies to stimulate the growth of SSF Supply

In this group of policies, we include what in the policy literature is called "technology-push policies"[96], which help reduce the cost of research and development, drive new ideas, and encourage adoption of early-stage technologies.[97]

i) Targeted financial incentives and tax relief to expand SSF supply infrastructure

The ICAO guidance suggests financing programs and tax policies that reduce the financial risk and tax burden of SSF projects, in order to support private-sector capital investment in SSF production.

One option would be to offer a Government Grant by the UKSA or the CCA to build or buy SSF-specific infrastructure. This can support and enhance the introduction of new actors into the production of SFF.

Another option is for businesses to take advantage of a tax incentive called bonus depreciation, which encourages investment by allowing them to depreciate qualifying assets, such as equipment, at a faster rate than usual. This means they can reduce their income tax and, as a result, their tax liability. Bonus depreciation is an important tax-saving tool for businesses, allowing them to take an immediate deduction on the cost of eligible business property in the first year. This lowers a company's tax liability because it reduces its taxable income.

Another possibility is the inclusion of a Business Investment Tax Credit (ITC) for SSF investments. This allows deduction of construction and/or commissioning costs of a qualifying asset which can reduce income tax payable and flow through to investors.

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[95] The Greenhouse Gas Emissions Trading Scheme Order (2020), < https://www.legislation.gov.uk/uksi/2020/1265/contents/made> accessed 1 December 2023.

[96] Ebadian, Van Dyk, McMillan, Saddler, "Biofuels policies that have encouraged their production and use: An international perspective" (vol. 147 2020) 1, <https://doi.org/10.1016/j.enpol.2020.111906> accessed 1 December 2023.

[97] Jordaana, S.M., Romo-Rabagob, E., McLearyb, R., Reidyb, L., Nazaric, J., Herremansb, I. M., 2017. "The role of energy technology innovation in reducing greenhouse gas emissions: a case study of Canada" (Renew. Sustain. Energy Rev. vol 78. 2017) 1397–1409.

A further option could be the development of green bonds. Green bonds are a type of fixed-income instrument that are specifically earmarked to raise money for climate and environmental projects. These bonds are typically asset-linked and backed by the issuing entity's balance sheet, so they usually carry the same credit rating as their issuers' other debt obligations.[98]

The UK has recently developed and published the Green Financing Framework 2021[99], based on the recommendations of the 2021 ICMA Green Bond Principles. This framework allows Eligible Green Expenditures to include government expenditures in the form of direct or indirect investment expenditures, subsidies, or tax foregone (or a combination of all or some of these) and selected operational expenditures. The eligible expenditures are limited to government expenditures that occurred no earlier than 12 months prior to issuance, the budget year of issuance, and the two budget years following issuance.

Within the list of Eligible Green Expenditures, the UK Green Taxonomy expressly includes those related to Climate Change Mitigation, such as "alternative fuels"[100]. A recommendation would be to invest in Green Bonds through the Green Financing Framework 2021, in order to secure funding for SFF infrastructure.

Finally, the UK could implement recommendations of the Taskforce on Nature-related Financial Disclosures (TNFD), which sets up full disclosure guidelines for corporate sustainability to be aligned with the global policy goals in the Kunming-Montreal Global Biodiversity Framework.[101] These baseline reporting criteria include the quantity (tonnes) of high-risk natural commodities sourced form land, by commodity and the volume of wastewater (m3) and concentration of key pollutants (mg/litre) used in SSF production. These disclosure and assessment metrics would then form the basis of a tax and liability strategy.

ii) Targeted financial incentives and tax relief to assist SSF facility operation

SSF production facilities face higher operating costs and risks compared to existing fuel suppliers. However, targeted financial incentives or tax credits can help bridge the cost gap between SSF and fossil jet fuel. Policy mechanisms that provide support to SFF production can address these challenges and make the production process more financially viable.

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98 https://www.investopedia.com/terms/g/green-bond.asp

99 UK Debt Management Office, "UK Government Green Financing Framework" (2021) < https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1002578/20210630_UK_Government_Green_Financing_Framework.pdf > accessed 1 December 2023.

100 Ibid 15.

101 TNFD, Taskforce on Nature-related Financial Disclosures Recommendations, September 2023, §3.3 "Recommended disclosures and guidance for all sectors", pp. 46-60, < https://tnfd.global/publication/recommendations-of-the-taskforce-on-nature-related-financial-disclosures/#publication-content > accessed 4 January 2024.

An option would be to introduce a Producer's Tax Credit ("PTC"). This would be an incentive targeted at the producers of fuels that provides a credit against taxes. This mitigates the cost of production difference between SSF and fossil jet.

Another option is to reduce or eliminate the tax in proportion to the quantity of SSF consumed, which would serve to incentivize fuel consumers to purchase SSF by contributing to lower SSF cost.

iii) Incentives for launch operators

Climate change agreements (CCAs) are voluntary agreements made by the UK industry and the Environment Agency to reduce energy use and carbon dioxide emissions. In return, operators receive a discount on the climate change levy (CCL), a tax added to electricity and fuel bills for non-domestic users, which rises each year in line with inflation.[102] As launch operators are charged with the CCL because of the usage of the fuel needed for launches, CCAs can be used to foster the usage of SSF within the space industry.

iv) Mandates for spaceports in the UK

An obligation for the UK spaceports could be established to provide the infrastructure necessary to facilitate the access of spacecraft operators to aviation fuels containing shares of sustainable aviation fuels.

v) Fostering "Sovereign Launch"

"Sovereign launch capability"[103] refers to the ability of a country to launch its own satellites into space independently without relying on foreign countries.

The UK has previously lacked a dedicated space launch site, but the development of spaceports such as Saxavord based in Shetland, Scotland, provides the UK with the necessary infrastructure to support UK space launches and creates further opportunities for the commercial launch of satellites by other countries. This enables the UK to establish its own best practices related to mission design, preparation for launch and launch. In particular, the UK should play a leading role in monitoring the debris paths of launches (including marine areas), and the parts of the atmosphere traversed by the launch vehicle. Areas affected by deorbiting missions should also be included, including the re-entry path and landing location of remnants, as at Point Nemo.

[102] UK Government, Guidance on Climate Change Agreements, < https://www.gov.uk/guidance/climate-change-agreements--2 > accessed 1 December 2023.
[103] Alan Belward and Jon O. Skøien. "Who Launched What, When and Why; Trends in Global Land-Cover Observation Capacity from Civilian Earth Observation Satellites" (*ISPRS journal of photogrammetry and remote sensing* 2015) 115–128.

Responses requested regarding views on establishing a UK space sustainability concept.

46. Do you have any views how these and other approaches and concepts could be used to inform the UK's developing policy on space debris?

Response:

No comment.

Responses requested regarding defining sustainability with regards to space activities.

47. Do you have any further suggestions as to how the long-term sustainability guidelines could be adapted for a UK space sustainability definition?

Response:

No comment.

48. Do you think that sustainability of the Earth's environment should also be included in the definition, and if so, how?

Response:

No comment.

49. If you agree that aspects of Earth sustainability should be included in this definition, which aspects should be covered in the proposed roadmap?

Response:

No comment.

Responses requested regarding international co-ordination on space sustainability.

50. Are there any additional actions with regards to space sustainability that could be taken forward through international fora such as UN COPUOS?

Response:

No comment.

51. Are there any lessons or actions arising from other multilateral issues tackled through international fora that could be applied to space sustainability?

Response:

No comment.

Responses requested regarding bilateral arrangements.

52. Are there any other activities which you feel could benefit from an approach agreed bilaterally as a template for wider use?

Response:

No comment.

Responses requested regarding insurance / finance sector.

53. Do you have any views on adopting measures similar to climate finance and insurance initiatives to promote space sustainability? If yes, please provide suggestions on possible actions that could be taken.

Response:

No comment.

Responses requested regarding Commercialisation of Active Debris Removal and In-Orbit Servicing Services.

54. Do you consider that applying targets for debris removal as part of the roadmap and taking action to remove debris created by future missions would create sufficient demand to ensure a sustainable ADR sector?

Response:

No comment.

55. Is any other regulatory action needed to facilitate ADR and IOS services?

Response:

No comment.

56. Do you have any suggestions or comments on how private finance could be secured to develop a UK ADR and IOS capability?

Response:

No comment.

57. Do you have any views as to whether governments should have a role in debris removal?

Response:

No comment.

58. Would you support the establishment of a global ADR fund, even if UK industry was not the primary beneficiary of such a fund?

Response:

No comment.

Responses requested regarding establishing a circular economy in space.

59. What do you consider to be feasible timescales for the development of a circular economy in space?

Response:

The transition to a circular economy in space is a multifaceted challenge that can only be accomplished over several decades. This is reflected in the approach adopted in the Scottish Space Sustainability Roadmap. While immediate steps can be taken in the next 3-5 years, achieving a comprehensive circular economy in space is a long-term goal, potentially spanning 30 years or more, contingent on technological advancements and global cooperation.

Short-Term (Next 3-5 Years) initiatives could include: developing and resourcing online platforms for data-sharing and collaboration among space agencies, researchers, and private companies; reviewing and considering the application of existing regulations relevant for a circular economy, developed outwith the space context; initiation of pilot projects that incorporate circular economy principles in space missions, utilising ICT techniques for monitoring and data analysis.

Medium-Term (5-15 Years): Enhance IT tools for more comprehensive data analysis and decision-making support. Evaluate pilot projects and build suitable incentive/regulatory mechanisms to encourage wide-scale adoption.

Longer term (15-30 Years), we could aim for a fully integrated circular economy model in major space missions. Continuous improvement and adaptation of IT tools to support these complex ecosystems.

60. What do you see as the key regulatory challenges and changes needed to establish a circular economy in space?

Response:

A key to accelerating this timeline is the active collaboration between governments, space agencies, the private sector, and academic institutions. This collaborative effort can lead to shared best practices, joint missions focused on sustainability, and pooling resources for technological advancements. Moreover, the development of a circular economy in space requires supportive policy frameworks. Given global competition and supply chains, action is necessary at international, as well as regional and domestic levels, to facilitate a level playing field and minimise the attraction of forum shopping. International agreements and regulations to incentivise, and in certain contexts mandate, sustainable practices and collaboration on waste management, minimising space debris, and efficient use of resources are required. The UK can play a key role in supporting networks and partnerships that help to design and facilitate such agreements.

Access to reliable and independent data is essential in order to establish appropriately ambitious standards and prevent 'greenwashing'. The digital sector can aid in creating these resources by providing data-driven insights and facilitating transparent global discussions.

Sustainability can be an economic driver for large firms with the resources to engage in research and development but imposes costs on small to medium scale operators that make up much of the UK space landscape. Policies and incentives thus need to be developed to support this sector and encourage their continuing commitment to a green space economy.

By establishing key priorities and actions, the UK Government can play a significant role in fostering space sustainability, leveraging the advancements in IT and technology to create a more responsible and efficient future in space exploration.

One final recommendation to achieve longer-term sustainability in the UK space sector is the emphasis on training and educational support. We recommend training courses for existing operators, emerging SMEs and the wider public, to increase participation towards sustainability modelling and policy in space. The UK Space Agency could be a key actor in the establishment of formal training courses. Funding PhD training, not just in technology but also related policy and legal dimensions, could also inform regulation and directly address the Space Skills Gap.

61. When do you think it will be feasible to stop satellites de-orbiting into the Earth's atmosphere?

Response:

No comment.

Responses requested regarding sustainability of the Lunar environment.

62. Do you have any thoughts on specific actions that can be taken to protect the Lunar environment and that of other planets and solar system bodies?

Response:

No comment.

Responses requested regarding priorities for action on space sustainability.

63. Based on the issues set out in this section, what do you consider to be the priority areas for action to protect the Earth's and low Earth orbital environments?

Response:

No comment.

This consultation response form is available from: https://www.gov.uk/government/consultations/call-for-evidence-to-inform-orbital-liability-and-insurance-policy

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