SPACE SUSTAINABILITY

A Roadmap for Scotland

Scottish Enterprise

Space Scotland

optimat

ASTROAGENCY

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TABLE OF CONTENTS

INTRODUCTION

BACKGROUND

The Scottish space sector is well established and has ambitious growth plans. The Scottish Government and its economic development agencies have identified that the **space sector is a key opportunity for future economic growth.** In 2019 Space Scotland established an Environmental Task Force working group, which aims to better understand the true impact of the space industry both on Earth and in Low Earth orbit to help **ensure that the rapidly evolving UK space sector develops in a sustainable manner.**

The new Scottish Space Strategy has identified sustainability as a key thread of Scotland's approach to space, alongside aiming to create 20,000 jobs and secure a £4 billion share of the global space market. Scottish Enterprise now seeks to turn strategic intent into a co-ordinated programme of action for industry, academia and the public sector through the development of a Sustainability Roadmap for the totality of the space industry in Scotland.

This report addresses that intent. It has been prepared jointly by AstroAgency Ltd and Optimat Ltd and presents the results of the preparation of the roadmap. The output from this research builds on the work of Space Scotland's Environmental Task Force and the Sustainable Space Challenges initiative.

EXECUTIVE SUMMARY

THE SCOTTISH SPACE SUSTAINABILITY ROADMAP

The space sector in Scotland is well established and has ambitious growth plans across its end-to-end value chain. The Scottish Government and its economic development agencies have identified the industry **as a key opportunity for future economic growth,** placing it among its top priority markets. With the country contributing more space sector employment per capita than anywhere else in the UK, Scotland's supporting role in the wider UK space ecosystem is more crucial than ever.

In 2019 Space Scotland established an Environmental Task Force working group, with a remit to better understand the true impact of the space industry both on Earth and in Low Earth orbit in order to help **ensure that the burgeoning UK space sector develops in a sustainable manner.**

The new strategy Space Sustainability: A Roadmap for Space Scotland, charts a path to a more sustainable Scottish space sector through a series of short, medium and long-term work packages. The roadmap was developed in consultation with leading international experts in space sustainability and stakeholders across the UK space sector, as well as engagement with other industries to find transferable examples of effective practice.

The Roadmap is believed to be the first strategic document of its kind to address this specific challenge, and will **help Scotland to play a leading role in demonstrating a sustainable approach to space-faring,** as well as helping the UK sector **contribute to the national Net Zero goal.** Taken as a whole, the recommendations in the Roadmap create a unique opportunity to ensure that the sector develops sustainably with a minimum impact on both the orbital and terrestrial environment. The following pages highlight key findings from this research, present the full details of the work packages, and showcase areas in which organisations in Scotland are already leading the way.

KEY FINDINGS

1. Existing space sustainability guidelines in the sector tend to **focus on preserving the space environment rather in addition protecting Earth's environment.**

2. Improving the sustainability of the space sector in orbit requires a **complicated, interrelated set of technical, economic, and political challenges** to be addressed.

3. There is no shortage of agreed-upon space sustainability guidelines, but these are not legally binding and rely on the voluntary goodwill of satellite operators and lack the stronger deterrent required for such a serious issue. Some existing legislation will be applicable to the protection of Earth's environment from the detrimental effects of launch activity, but **the absence of space specific legislation for Earth and Low Earth Orbit is a key blocker to pursuing a sustainable space industry.**

4. Unilaterally imposing regulations on the space industry without their involvement and endorsement of the proposed rules is a counterproductive approach.

5. It may be impossible to compel Scottish space companies to behave sustainably, but by providing funding and support for sustainable initiatives it is possible to encourage sustainable behaviours.

6. **The Scottish space sector would greatly benefit from direct, structured** guidance and "carrots" — financial support and incentives to support space sustainability. However, developing a sustainable Scottish space sector will also require "sticks" — legislative or financial means of deterring unsustainable behaviour.

KEY FINDINGS

7. While the many exciting and innovative efforts to improve space sustainability in Scotland should be applauded and showcased to demonstrate an impressive rate of progress, **there is also a danger of 'Greenwashing' fundamentally unsustainable activities.** Companies, organisations and individuals making claims of sustainability must provide transparent, convincing evidence of their claims. Fostering a culture of healthy constructive criticism of sustainability claims in the Scottish Space Sector will be vital to achieving this aim.

8. **There is currently a unique opportunity to ensure that the formative Scottish space sector develops sustainably.** The sector is young and fast-growing, with comparatively few vested interests and many emerging companies and capabilities. Investing time and resources into the Scottish space sector now will embed sustainability into the sector as it grows, allowing a more environmentally conscious space ecosystem and providing Scotland with an opportunity to demonstrate its genuine desire to lead in this area globally.

9. **There is a lack of agreed-upon, widely adopted metrics and targets for space sustainability.** There is no set limit on how many satellites can operate in a given orbital region and even the definition of space sustainability is debated; hence, our proposed definition. Some metrics have been adopted (such as the 25-IADC rule or the casualty risk on ground that determines satellite end-of-life) but overall targets for sustainable spacefaring do not yet exist.

10. The mitigation measures described in this document and established **space sustainability guidelines need to be implemented effectively immediately to preserve the space environment.**

ENVIRONMENTAL IMPACTS OF THE SPACE SECTOR

Space Debris makes space operations more challenging.
(See Work Packages 1.4 & 2.3)

Constructing Rockets, Satellites, and Spaceports uses resources and causes CO_{2eq} emissions.
(See Work Package 1.6)

Material from ***re-entering Satellites*** has detrimental effects on the ozone layer.
(See Work Package 1.6)

Falling Rocket Stages pollute the marine environment.
(See Work Package 2.4)

Astronomical observations are contaminated by satellites.
(See Work Package 1.4)

Rocket Engines emit across the entire atmosphere, causing radiative forcing and depleting ozone.
(See Work Package 2.4)

Operating Satellites and Processing Space Data is energy-intensive.
(See Work Package 1.6)

Designing and Testing Satellites is work-intensive and energy-intensive. Space supply chains and logistics can have large environmental impacts
(See Work Package 1.6)

ECOSPHERIC IMPACTS

OZONE DEPLETION

Ozone is depleted by ClOx, NOx, HOx and HCl emissions during launch, particularly due to the combustion of the solid propellants.

AIR ACIDIFICATION

The production and manufacturing of launcher and spacecraft propellants contributes to air acidification due to the amount of sulphur dioxide, nitrogen oxides and ammonia released during the cryogenic air separation process.

FRESHWATER ECOTOXICITY

Spacecraft components contributes to freshwater aquatic ecotoxicity due to the release of arsenic, mercury and dioxins during the production and manufacturing of germanium for solar panels. The production of spacecraft propellants also contributes due to the release of ions to groundwater.

SOURCE: Wilson, A. R., Vasile, M., Maddock, C. A., & Baker, K. J. (2022). Ecospheric life cycle impacts of annual global space activities. Science of the Total Environment, 834, 155305.

WHAT IS SPACE SUSTAINABILITY?

The United Nations (UN) Committee on the Peaceful Uses of Outer Space (COPUOS) was set up by the General Assembly in 1959 to **govern the exploration and use of space for the benefit of all humanity: for peace, security and development.** The Committee was tasked with reviewing international cooperation in peaceful uses of outer space, studying space-related activities that could be undertaken by the United Nations, encouraging space research programmes, and studying legal problems arising from the exploration of outer space.

In 2018, it set out guidelines for the Long-term Sustainability of Outer Space Activities and provided the following definition of Space Sustainability:

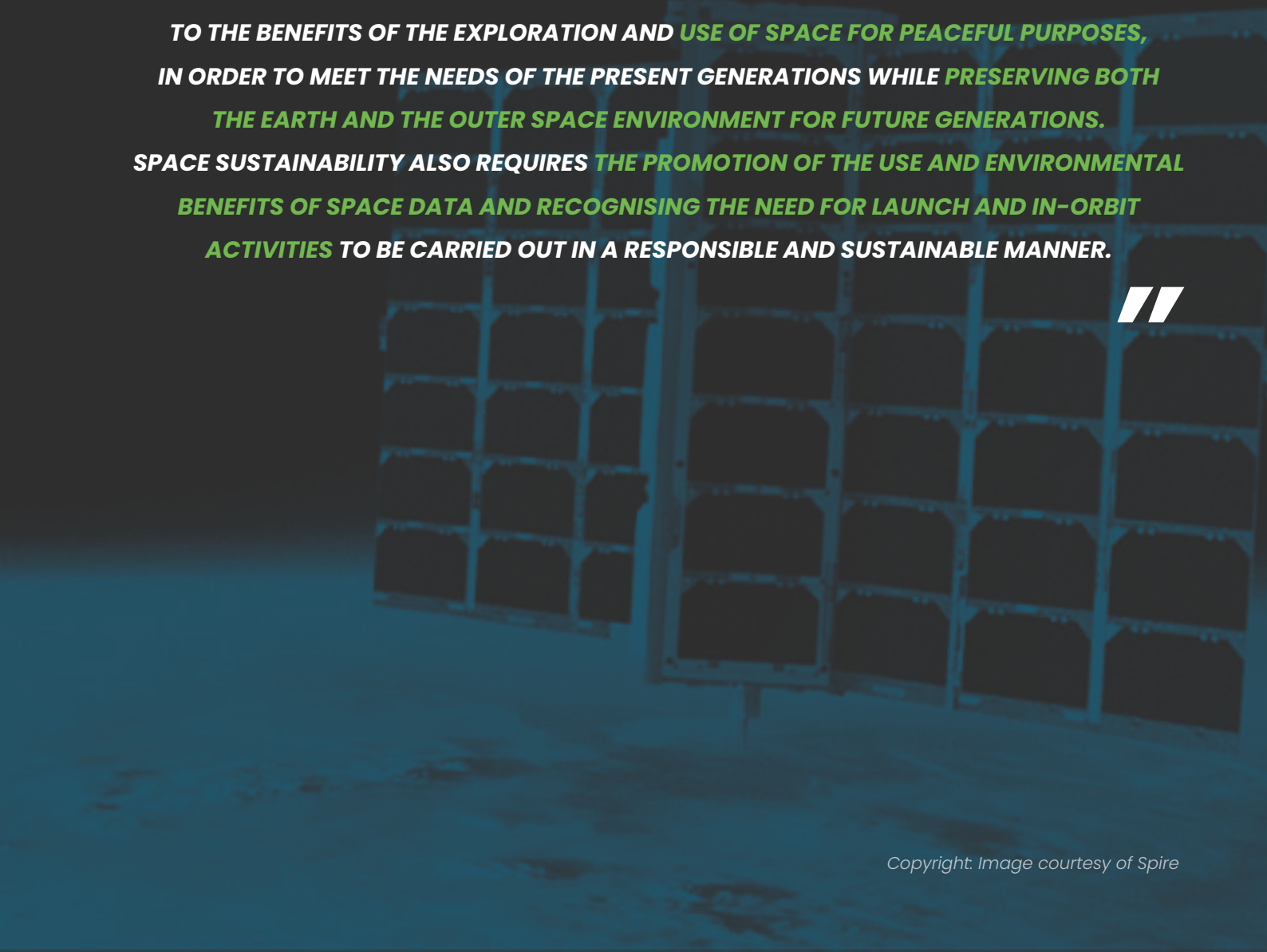
> ***THE LONG-TERM SUSTAINABILITY OF OUTER SPACE ACTIVITIES IS DEFINED AS THE ABILITY TO MAINTAIN THE CONDUCT OF SPACE ACTIVITIES INDEFINITELY INTO THE FUTURE IN A MANNER THAT REALISES THE OBJECTIVES OF EQUITABLE ACCESS TO THE BENEFITS OF THE EXPLORATION AND USE OF OUTER SPACE FOR PEACEFUL PURPOSES, IN ORDER TO MEET THE NEEDS OF THE PRESENT GENERATIONS WHILE PRESERVING THE OUTER SPACE ENVIRONMENT FOR FUTURE GENERATIONS.***

This is a widely accepted and reputed definition; consequently, this was used as a starting point for defining space sustainability in a Scottish context. However, **the UN COPUOS definition focuses mainly on the sustainability of activities in space,** with a particular focus on mitigating space debris and preserving the space environment. This definition was discussed during industry and stakeholder engagement and was amended to better align with both current practices in Scotland and with the broader aims of this roadmap.

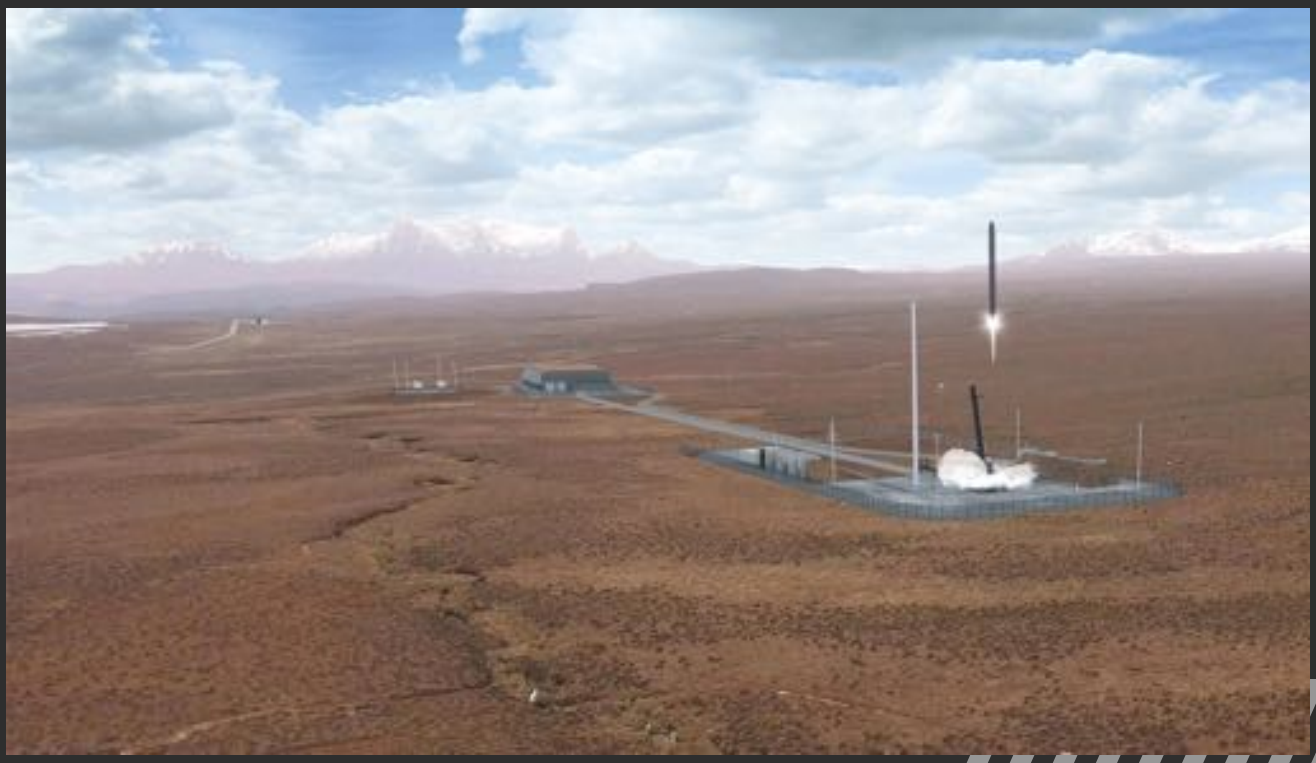
WHAT IS SPACE SUSTAINABILITY?

The following definition has been agreed upon with industry and key stakeholders:

> ***"THE LONG-TERM SUSTAINABILITY OF SPACE ACTIVITIES (ON-GROUND AND IN-ORBIT) IS DEFINED AS THE ABILITY TO MAINTAIN AND IMPROVE THE CONDUCT OF SPACE ACTIVITIES INDEFINITELY INTO THE FUTURE IN A MANNER THAT ENSURES CONTINUED ACCESS TO THE BENEFITS OF THE EXPLORATION AND USE OF SPACE FOR PEACEFUL PURPOSES, IN ORDER TO MEET THE NEEDS OF THE PRESENT GENERATIONS WHILE PRESERVING BOTH THE EARTH AND THE OUTER SPACE ENVIRONMENT FOR FUTURE GENERATIONS. SPACE SUSTAINABILITY ALSO REQUIRES THE PROMOTION OF THE USE AND ENVIRONMENTAL BENEFITS OF SPACE DATA AND RECOGNISING THE NEED FOR LAUNCH AND IN-ORBIT ACTIVITIES TO BE CARRIED OUT IN A RESPONSIBLE AND SUSTAINABLE MANNER."***



WHAT IS SCOTLAND ALREADY DOING?



GREEN SPACEPORTS

Highlands and Islands Enterprise, with financial support from the UK Space Agency, are **developing the Space Hub Sutherland spaceport facility at A' Mhòine in Sutherland.** The spaceport will be purpose-built for small satellite launches at an expected initial cadence of 12 launches a year. Of the just over 1000-hectare site, 4.2 hectares would be developed to include a control centre, a launch site integration facility, the launch pad complex, an access road, fencing and services. Planning permission was granted in August 2020 subject to 34 conditions, many of which were to be met before construction began. The plans were also approved by the Scottish Land Court in September 2021. **The spaceport is being built with four sustainable "pillars" in mind: Economic, Environmental, Social and Human.** Space Hub Sutherland (SHS) is aiming to be the world's greenest spaceport and is prioritising a sustainable approach to spaceflight.

CASE STUDIES

Copyright: Image courtesy of Skyrora

GREENER PROPELLANTS

Propellants are the combination of oxidisers and fuels which —when combined— provide the thrust required to propel vehicles into orbit. **Typical propellants (such as kerosene or hydrazine) are toxic, dangerous to handle, often derived from fossil fuels, and difficult to store and transport.** These propellants need to be highly purified for effective and efficient burning and, as a result, they can be energy and resource-intensive to produce. Green propellants are designed to reduce the environmental impacts of propellants production and combustion. **In Scotland, different approaches are being taken to develop greener propellants,** including repurposing waste from biodiesel production and using non-recyclable plastics. Local launch companies Skyrora, HyImpulse Technologies and Orbex are leading these efforts.

GREENER SPACE SYSTEMS

STRATHcube is a "CubeSat that encourages the sustainable usage of space" and a project under development at the University of Strathclyde. The 2U CubeSat, which measures 10x10x20 cm, will carry an antenna to demonstrate in-orbit space debris detection and a sensor package that will analyse the CubeSat's fragmentation during atmospheric reentry. Furthermore, the design of the CubeSat incorporates Life Cycle Engineering, a design-stage engineering technique for assessing the environmental, social, economic and technical impacts of products, processes and services over their entire life cycle. **STRATHcube represents Scotland's ability to manufacture small, green space systems.**

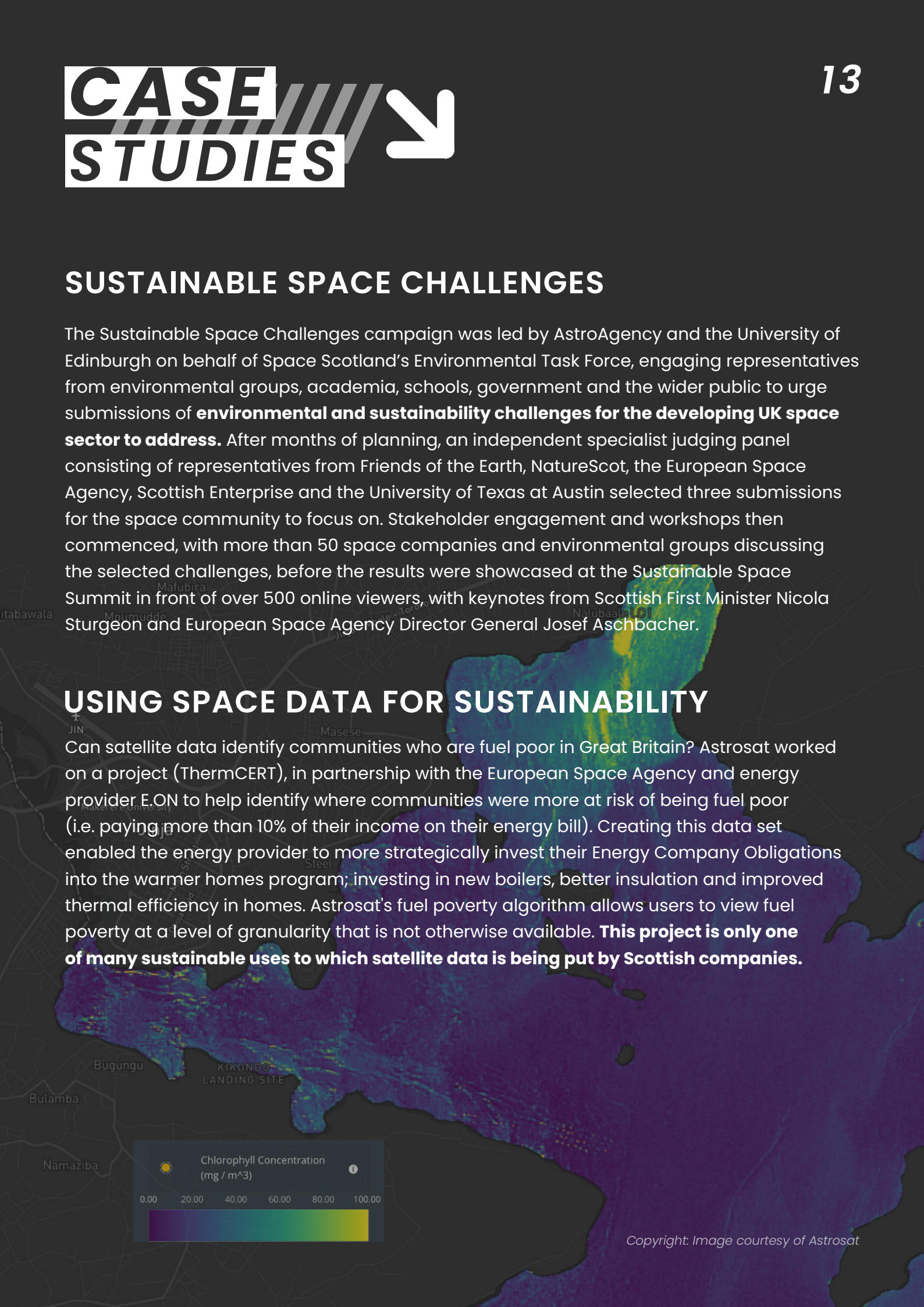
Copyright: Image courtesy of the University of Strathclyde/StrathAIS

SUSTAINABLE SPACE CHALLENGES

The Sustainable Space Challenges campaign was led by AstroAgency and the University of Edinburgh on behalf of Space Scotland's Environmental Task Force, engaging representatives from environmental groups, academia, schools, government and the wider public to urge submissions of **environmental and sustainability challenges for the developing UK space sector to address.** After months of planning, an independent specialist judging panel consisting of representatives from Friends of the Earth, NatureScot, the European Space Agency, Scottish Enterprise and the University of Texas at Austin selected three submissions for the space community to focus on. Stakeholder engagement and workshops then commenced, with more than 50 space companies and environmental groups discussing the selected challenges, before the results were showcased at the Sustainable Space Summit in front of over 500 online viewers, with keynotes from Scottish First Minister Nicola Sturgeon and European Space Agency Director General Josef Aschbacher.

USING SPACE DATA FOR SUSTAINABILITY

Can satellite data identify communities who are fuel poor in Great Britain? Astrosat worked on a project (ThermCERT), in partnership with the European Space Agency and energy provider E.ON to help identify where communities were more at risk of being fuel poor (i.e. paying more than 10% of their income on their energy bill). Creating this data set enabled the energy provider to more strategically invest their Energy Company Obligations into the warmer homes program; investing in new boilers, better insulation and improved thermal efficiency in homes. Astrosat's fuel poverty algorithm allows users to view fuel poverty at a level of granularity that is not otherwise available. **This project is only one of many sustainable uses to which satellite data is being put by Scottish companies.**

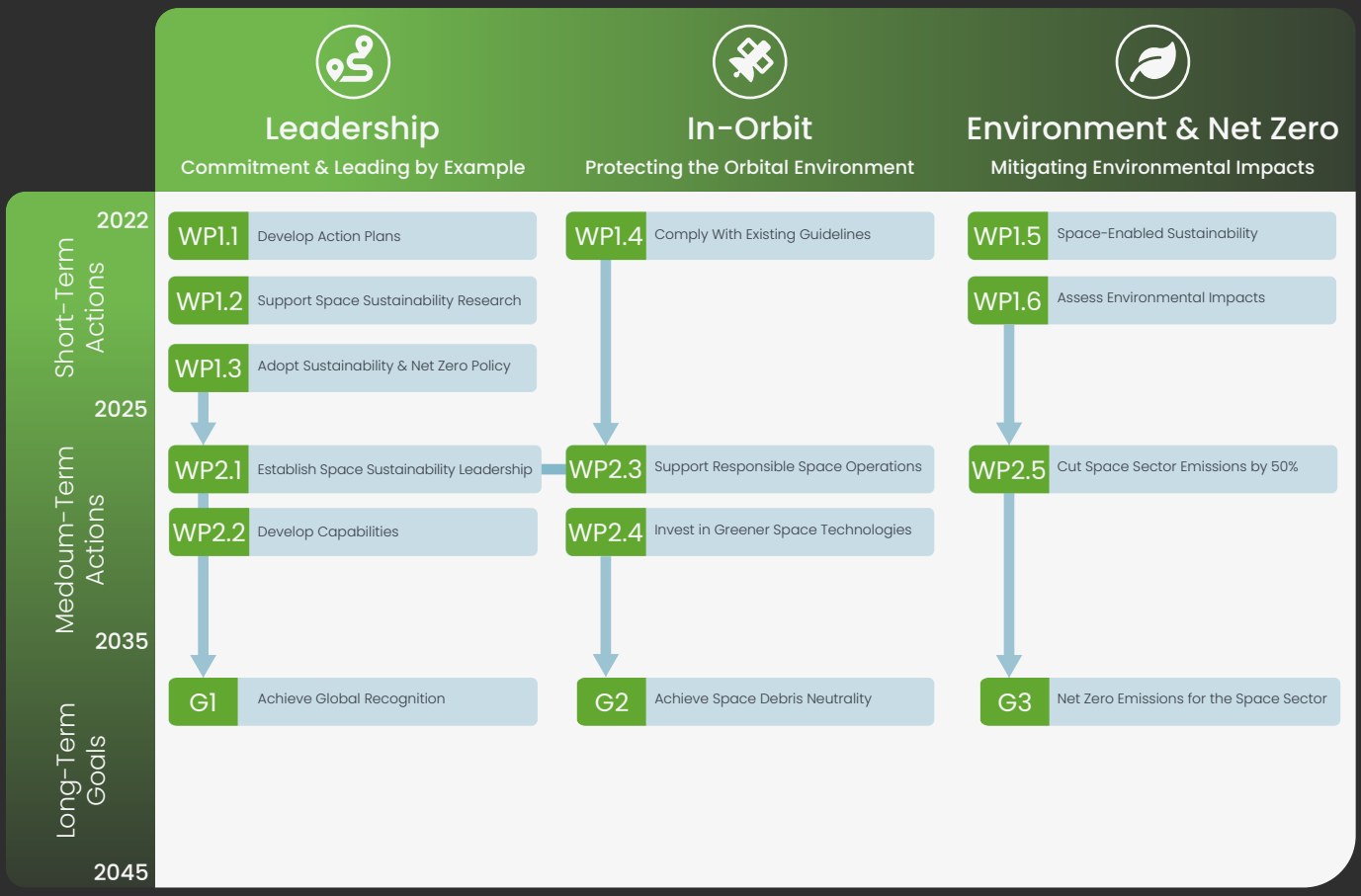


Copyright: Image courtesy of Astrosat

THE SPACE SUSTAINABILITY ROADMAP

The Scottish Space Sustainability Roadmap was developed based on a review of international effective sustainability practices in both space and non-space sectors, as well as through industry and stakeholder engagement in Scotland.

The Roadmap consists of **11 detailed Work Packages** organised into **three thematic areas: Leadership, In-Orbit, and Environment & Net Zero.** The Leadership work packages focus on planning, public commitments to sustainability, and national or international promotion of space sustainability. The In-Orbit work packages chart a path to sustainable space operations and contain actions to encourage responsible spacecraft operations and space debris mitigation. Finally, the Environment & Net Zero work packages chart a path towards understanding and mitigating the emissions and environmental impacts of the space sector. These work packages are sorted into short, medium and long-term actions, which are to be completed by 2025 and 2035 respectively. **The roadmap also sets out 3 goals for the sector to achieve by 2045 encompassing sustainability both on the ground and in orbit,** as well as the reduction of emissions by the space sector.



Work Package 1.1
Leadership

Develop Action Plans for Work Packages

Creating an environment that will enable the Scottish space sector to show global leadership through its sustainable approach to space requires a detailed, overarching set of action plans with resources and central coordination. Similarly, reducing the emissions of the sector to reach Net Zero will require coordination and support from government.

Action 1.1.1

PREPARE ACTION PLANS FOR WORK PACKAGES

Space Scotland's Environmental Task force in partnership with Scottish Government and its partner agencies to lead and oversee the preparation of action plans for each work package, including setting targets and metrics, and securing political and financial support for its development, formalisation, and implementation. Establish appropriate oversight, KPIs, promotional plans, and a timeline over which to revise the action plans if required. As part of this planning process, assess the current legislative landscape in the form of international regulation and relevant domestic legislation to identify any gaps in applicable space or environmental law pertaining to space sustainability.

Action 1.1.2

NOMINATE ORGANISATIONS RESPONSIBLE FOR IMPLEMENTING ACTION PLANS

Nominate responsible organisations to implement action plans. These nominated bodies will coordinate the action plans, advocate for their funding and liaise between space sustainability initiatives in Scotland. Nominate a body — ideally an industry representative such as Space Scotland — to take ownership of the Space Sustainability and Net Zero roadmap on behalf of Scottish Enterprise. As part of this process, appoint a third party group with a mixture of environmental and space sector experience to monitor and assess progress on the action plans against the roadmap.

Action 1.1.3

ESTABLISH FUNDING AND RESOURCES

Review Scottish, UK and international funding sources to establish the funding required to foster sustainable development of the space sector in Scotland and establish what resources will be available to facilitate the work packages in this roadmap.

Work Package 1.2
Leadership

Support Space Sustainability Research

Provide support and funding to enable the identification of environmental impacts of the space sector and to develop the technologies required to mitigate against them.

Action 1.2.1

MAKE FUNDING AVAILABLE FOR SPACE SUSTAINABILITY PROJECTS WITHIN SCOTLAND

Provide or source strategic ongoing funding for high-impact research and development projects in Scotland to advance the goals of the action plan (A1.1.1), develop new capabilities or accelerate work on existing projects. For example, two of Scotland's launch vehicle companies are working on greener propellants. Take advantage of expertise and best practices from innovation centres such as CENSIS and The Data Lab.

Action 1.2.2

FUND RESEARCH INTO THE ENVIRONMENTAL IMPACTS OF SPACE ACTIVITIES

Solicit and fund research proposals to investigate the environmental impacts of space activities on the atmosphere which close gaps in the sector's knowledge of the environmental impacts of launch and re-entry. Engage with research councils and advocate for funding on relevant projects.

Work Package 1.3
Leadership

Adopt Sustainability & Net Zero Policy

Public commitments to sustainability will both establish Scotland as a leading nation in space sustainability and provide accountability to cutting emissions and improving the sustainability of the sector.

Action 1.3.1

COMMIT TO THE PARIS PEACE FORUM NET ZERO SPACE PLEDGE

A representative Scottish organisation such as Space Scotland commits to supporting the "Net Zero Space" initiative, potentially on behalf of interested space companies. When announcing their support, the organisation will commit to declaring concrete, tangible examples of proposed actions they are taking towards the sustainable use of space and reducing orbital debris.

Action 1.3.2

PUBLICLY COMMIT TO CUTTING EMISSIONS BY 2045

Space Scotland makes a high-level public commitment to reducing emissions in the Scottish space sector based on the initial assessment in A1.6.1 and the action plans outlined in A1.1.1. Set quantifiable interim targets for the short- and medium-term which contribute to the 50% global reduction in CO2 equivalent by 2030 targeted by the Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5C° and to the wider Scottish goal of achieving Net Zero by 2045.

Work Package 1.4
In-Orbit

Comply With Existing Guidelines

Compliance with space sustainability guidelines such as the IADC Space Debris Mitigation Guidelines imposes a cost on space companies, as does obtaining certification such as Space Sustainability Ratings. Providing support to meet these goals will help make the Scottish space sector both environmentally and economically sustainable.

Action 1.4.1

RAISE AWARENESS OF SPACE SUSTAINABILITY WITHIN THE SCOTTISH SPACE SECTOR

Hold workshops, publish papers, showcase progress at events, and prepare summaries on pressing issues in space sustainability for both a mainstream and industry audience, to ensure that the awareness of space sustainability issues and existing guidelines is widespread. Also highlight the peripheral impacts of space activities such as the impact of satellite constellations on astronomical observations. Develop a digital resource showcasing case studies, current issues, best practises, and promote its use in the sector and by government. Use workshops and links to existing resources to provide the Scottish space sector with guidance on effective space sustainability practices.

Action 1.4.2

INCENTIVISE SCOTTISH SPACE SECTOR TO COMPLY WITH EXISTING GUIDELINES

Engage with Scottish satellite manufacturers and operators to assess compliance with the IADC Space Debris Mitigation Guidelines, UN COPUOUS Guidelines on the Long-term Sustainability of Outer Space Activities, the Best Practices for the Sustainability of Space Operations, the SO 24113:2019 Space Debris Mitigation Requirements, and the UN Sustainable Development Goals. Where these guidelines are not being met —for example, if small satellites cannot be passivated at the end of mission — provide support and incentives for companies to comply with existing guidelines.

Action 1.1.3

FUND SCOTTISH MISSIONS TO OBTAIN SPACE SUSTAINABILITY RATINGS

Provide financial support for 1-3 operators with a presence in Scotland, to obtain Space Sustainability Ratings (SSR) for their missions from EPFL. The SSR will enter its operational phase in Q1/Q2 2022, and early adoption by Scottish companies will demonstrate the sector's commitment to sustainability. Ideally make this funding available on a rolling basis.

Work Package 1.5
Environment & Net Zero

Space-Enabled Sustainability

Satellite imagery can help other sectors to make more sustainable decisions as well as monitor the state of our planet. However, the challenges of non-space business and the capabilities of the downstream space sector need to be coordinated.

Action 1.5.1

PROMOTE THE SUSTAINABILITY BENEFITS OF SPACE DATA

Raise awareness within non-space sectors of the benefits and applicability of space data to sustainability challenges through outreach and workshops building on similar initiatives already launched in Scotland.

Action 1.5.2

CONNECT SCOTTISH COMPANIES WITH SPACE DATA

Build the capabilities of companies in Scotland to provide space data-enabled solutions to address challenges in other sectors following the model of Space4Impact in Switzerland. Foster connections between SMEs and experts who can demonstrate how to derive value from space data, as well as supporting start-ups making innovative use of satellite data.

Action 1.5.3

SUPPORT COMPANIES TO DEVELOP INNOVATIVE ANALYTICS

Building on Edinburgh's status as the emerging "Space Data Capital of Europe" and following A1.5.1 and A1.5.2, support Scottish companies developing innovative analytics for satellite data. Particularly focus on efforts which could provide sustainability benefits to other sectors, or which analyse data on space debris and space situational awareness. This support could consist of funding for low Technology Readiness Level projects, assistance in attracting talent to Scotland, or fostering partnerships between Scottish companies and international partners.

Work Package 1.6
Environment & Net Zero

Assess Environmental Impacts

The environmental footprint of the space sector is unknown, and it is vital to estimate the CO2 equivalent emissions of the Scottish Space Sector to provide a baseline for plans to cut emissions. Effective practices from other sectors can readily be applied to the space sector.

Action 1.6.1

DETERMINE CURRENT EMISSIONS IN THE SCOTTISH SPACE SECTOR

Using data from companies, projects such as the Strathclyde Space Systems Database, and best practices from other sectors, draw up an estimate of the total CO2 equivalent emissions of the Scottish space sector capturing emissions across the space segment, launch segment and ground segment of space missions, as well as infrastructure, including embodied CO2 equivalents. Also account for or estimate the emissions of the downstream space sector, particularly the emissions caused by space data storage and analysis and the embodied CO2 equivalent of existing infrastructure. This figure for aggregate space sector emissions will be the baseline for future emissions reductions. Identify hotspots of intense emissions in the space sector.

Action 1.6.2

SUPPORT LIFE CYCLE ASSESSMENTS FOR SCOTTISH SATELLITES

Accurate data on the environmental impacts of satellite components and manufacturing processes are lacking. Scotland already has the expertise to apply ESA's Space Systems Life Cycle Assessment framework via researchers at the University of Strathclyde and establishing the "hot points" of environmental impacts of industrial satellite and satellite component manufacture is the first step towards mitigating these impacts. To make space system LCAs more widely applicable, it is necessary to incentivise Scottish satellite manufacturers to share data on the environmental impacts of their satellites, and thereby provide the source data for LCAs.

Action 1.6.3

ASSESS WIDER IMPLICATIONS OF NEW SPACE INFRASTRUCTURE

Beyond the environmental impacts detailed in the planning process, assess the wider implications of new space infrastructure such as spaceports, manufacturing and operations, such as the increased burden on transport infrastructure and the effects of launch on wildlife.

Action 1.6.4

DEVELOP AN ACTION PLAN TO CUT EMISSIONS

Based on the hotspots and emissions identified by A1.6.1 and A1.6.2, develop a detailed plan outlining the proposed actions required to make realistic cuts to emissions. Focus on quick, easy-to-implement proposed actions in the short term which can immediately cut CO2 equivalent emissions if implemented. Also outline a procedure to report progress towards cutting emissions on a yearly basis. Following the lead of the aviation sector, develop science-based targets to reduce the emissions of the space sector focussing on cutting emissions where possible and offsetting any residual emissions. Within this strategy, define rules and guidelines for carbon offsetting within the Scottish Space Sector to avoid greenwashing, and ensure that carbon offsets are not used in place of achievable emission reduction measures.

Work Package 2.1
Leadership

Establish Space Sustainability Leadership

Raising awareness of space sustainability initiatives and successes in Scotland will be vital not only for encouraging further sustainability within the sector, but also in securing investment, high-skilled talent, and prominence for the sector.

Action2.1.1

CREATE SCOTTISH SPACE SUSTAINABILITY PLEDGER

Tie funding eligibility to sustainable criteria and setting out a commitment to increasingly sustainable operations, modelled on the Scottish Business Pledge and the Kitemark. Link this to existing international initiatives such as the Space Sustainability Rating.

Action 2.1.2

PROMOTE THE NEED FOR LEGISLATIVE CHANGE TO CATALYSE A MORE SUSTAINABLE SECTOR

Work towards a legislative basis for space sustainability in Scotland based on the gaps identified in A1.1.1 and the experience gained by industry while applying the short-term actions of the roadmap. Building on examples such as the French Space Operations Act, lobby for specific, UK-wide space sustainability legislation which mandates compliance with space sustainability guidelines for UK satellites and launches. At a minimum,work to ensure the guidelines of the IADC and the UN COPUOS become legally binding.

Action 2.1.3

RAISE INTERNATIONAL AWARENESS OF SPACE SUSTAINABILITY PROPOSED ACTIONS IN SCOTLAND

Raise the international profile of Scottish space activities nationally and internationally to catalyse similar efforts and position Scotland as a leader in space sustainability. There is also an opportunity to develop links with other organisations and countries promoting space sustainability. Promote the resources developed in A1.4.1.

Action 2.1.4

DRIVE UK SPACE AGENCY SPACE SUSTAINABILITY INITIATIVES

The UK Space Agency is working to establish leadership in space sustainability in line with the UK Space Strategy. To make as much of an impact as possible, it is vital to align with space sustainability initiatives in the wider UK to avoid duplication of effort and to pool resources effectively. This can be achieved, for example, through ongoing collaboration with the UK Space4Climate Net Zero task force. The Scottish space sector can act as a flagship region for sustainability within the UK and lead by example.

Work Package 2.2
Leadership

Develop Skills and Capabilities

Enabling the Scottish space sector to be sustainable will also require skills, expertise, and capability to be built up and retained within the sector. As well as training graduates and apprentices with space sector skills, programmes should be established to transfer knowledge and effective sustainability practises between space sector companies.

Action2.2.1

DEVELOP SKILLS IN THE SCOTTISH SPACE SECTOR

Support the development of specific skills within the Scottish Space Sector by, for example, providing scholarships to ESA's Industrial Space Life Cycle Assessment Course or organising bilateral sessions with leaders in other sectors to transfer best practice. Ensure that the sector has the necessary skills for the future by supporting the Scottish Space Academic Forum and engaging with Scottish universities offering courses relevant to the space sector. Support the development of green space sector jobs and contribute to the just transition in Scotland.

Action 2.2.2

ESTABLISH A GROUND-BASED FACILITY FOR SPACE SITUATIONAL AWARENESS

Scotland's geographic location is well-suited to monitoring polar and sun-synchronous Low Earth Orbits. Building on Scottish expertise at the University of Strathclyde and the capabilities of the Scottish industry, establish a ground-based space situational awareness facility at a Scottish space cluster and share the data internationally. Alternatively, encourage an existing commercial SSA provider such as LeoLabs to establish a facility in Scotland.

Action 2.2.3

PROVIDE SUSTAINABILITY ADVISORS TO SUPPORT SPACE COMPANIES

Support the development of a new programme modelled on the successful Made Smarter initiative which will help space companies understand and promote sustainable practices. Create a small team of sustainability advisors who can support companies to adopt sustainable manufacture and ensure that companies can access relevant supply chains in a sustainable and economical way. This programme would be especially helpful for start-ups and smaller companies, as well as potentially boosting programmes like the Kickstart scheme by encouraging the employment of early careerists and students into roles aimed at promoting companies' sustainability values.

Work Package 2.3
In-Orbit

Support Responsible Space Operations

To complement conditional governmental funding which depends on Net Zero plans, create an incentive to encourage in-orbit sustainability in the Scottish space sector by developing a voluntary scheme similar to the Scottish Business Pledge or the Space Sustainability Rating. Tie the availability or proportion of government funding to being able to display this credential.

Action2.3.1

PROMOTE RESPONSIBLE SPACECRAFT OPERATIONS FROM SCOTLAND

Advocate to ensure that all satellites launched from or manufactured in Scotland are capable of performing collision avoidance manoeuvres in orbit and will re-enter the atmosphere immediately or within 1 year of end-of-mission. Steps to support this activity could include, for example, advocacy or financial support to include propulsion systems or deorbit devices on satellites.

Work Package 2.4
In-Orbit

Invest in Greener Space Technologies

Designing sustainable spacecraft requires minimisation of environmental impacts both on ground and in orbit. A greener approach to space technology could also encompass deciding whether or not specific launches can proceed based on the balance of their societal benefits and environmental impacts.

Action2.4.1

SUPPORT ECODESIGN AND DESIGN FOR DEMISE FOR SCOTTISH CUBESATS

Build on industrial and academic expertise in Scotland to support Scottish CubeSat manufacturers with financial incentives to perform EcoDesign — to design new small satellites with the aim of minimising end-to-end environmental impacts from the outset. Aim to liaise with the ESA Clean Space Team to benefit from existing expertise and best practises and incorporate outcomes from WP1.4.

Action2.4.2

PHASE OUT TOXIC PROPELLANTS

Replace toxic propellants such as hydrazine in Scottish launchers and satellites with more environmentally friendly alternatives wherever possible.

Action2.4.3

CONSIDER SUSTAINABILITY BEFORE ALLOWING LAUNCH

Require companies to demonstrate a clear sustainability plan before launch and require a positive societal benefit that outweighs the environmental impacts of a launch.

Action2.4.3

SUPPORT DEVELOPMENT OF SUSTAINABLE CUBESAT TECHNOLOGY

Support small satellite manufacturers in Scotland such as Spire and Clydespace to develop and adopt technologies to make CubeSats more sustainable, such as propulsion for collision avoidance, deorbiting capabilities for faster re-entry, or adaptations to make them more detectable from ground.

Work Package 2.5

Environment & Net Zero

Cut Space Sector Emissions by 50%

The IPCC and European Commission have suggested targets of reducing emissions by 50% by 2030. The Scottish target is a 75% reduction in emissions by 2030 relative to 1990 emissions, but the space sector is lagging behind other sectors in emission reductions. Cutting emissions by 50% by 2030 is therefore a demanding, responsible, but achievable interim goal.

Action2.5.1

PROCEED AND PUBLISH

Carry out the plans developed in A1.1.1 while annually publishing progress against short- and long-term targets as well as details and case studies of Proposed Actions taken. Ensure that these publications are detailed and publicly available. Iteratively amend the plans developed in A1.1.1 as necessary and as new technologies or mitigation strategies become available.

Action 2.5.2

CUT EMISSIONS FOR THE SCOTTISH SPACE SECTOR BY 50%

In line with the action plans developed in A1.1.1 and the ongoing efforts of A2.5.1, achieve the target of 50% reduction in CO2 equivalent emissions for the sector by 2030, as targeted by the IPCC Special Report on Global Warming of 1.5C°.

THE SPACE SUSTAINABILITY ROADMAP

Goal 1

Achieve Global Recognition for Sustainable Spacefaring

To complement conditional governmental funding which depends on Net Zero plans, create an incentive to encourage in-orbit sustainability in the Scottish space sector by developing a voluntary scheme similar to the Scottish Business Pledge or the Space Sustainability Rating. Tie the availability or proportion of government funding to being able to display this credential.

Goal 2

Achieve Space Debris Neutrality

Ensure that for every Scottish launch which leaves debris in orbit an equal amount of debris from previous Scottish missions is removed from orbit (assuming that commercial active debris removal services are available).

Goal 3

Net Zero Emissions for the Space Sector

In line with the action plans developed in A1.1.1 and the ongoing efforts of A2.5.1 to reduce emissions, report progress, and offset emissions only where strictly necessary, achieve the target of net zero emissions for the sector by 2045, in line with Scotland's wider aim of net zero by 2045.

Space Sustainability
A Roadmap for Scotland