

Institution: University of Leicester

Unit of Assessment: UoA7

1. Unit context and structure, research and impact strategy

UoA7 at the University of Leicester (UoL) covers a broad spectrum of the Earth and Environmental Sciences reflecting the complex nature of our planet. We investigate and model diverse planetary processes—from mantle dynamics to the molecular composition of the atmosphere—traversing vast timescales, from the fundamental interpretation of 500 million year-old ecosystems through to human impacts on terrestrial vegetation and the carbon cycle. Questions of sustainability and future states of a rapidly evolving Earth System are newly emerging research themes. The scale of the questions addressed drives us to embrace diversity and collaboration in the pursuit of research excellence. This has become part of our core identity and underpins our future aspirations. Our integrated Research and Impact (R&I) strategy, with a clear set of shared goals, has created a stimulating and nurturing environment and improved performance across all areas of R&I during the REF2021 cycle. Highlights include:

1. **World-leading research on carbon storage in, and greenhouse gas (GHG) emissions from, organic soils.** This has driven global government and NGO policies to protect carbon-rich peatlands, improved awareness and knowledge of the environmental impacts of peatland agriculture, and contributed to renewable energy directives and climate change initiatives (**Page**, Impact Case Study 3, ICS3).
2. **Development of novel greenhouse gas measurement algorithms using space-based observations to identify national emissions and their sources/sinks.** These models underpin support of climate change action and leading activities in the production of United Nations World Meteorological Organization (WMO) Essential Climate Variable Datasets in Greenhouse Gases (**Boesch**, ICS1) and Fire Disturbance (**Tansey**).
3. **Developing the Anthropocene concept** via leadership of data-driven research into its definition, starting point, and scientific impacts, combined with substantial contributions to transforming socioecological understanding of our Planet in the arts and humanities (**Williams**, Zalasiewicz).
4. **Transforming understanding of the onset of global and hemispheric warming trends** from anthropogenic greenhouse gases as reflected in novel datasets derived from corals (**Zinke**).
5. **Powerful new models of mineral deposit formation**, leading to more sustainable exploration and extraction of resources and the development of new ways of processing metal ores to reduce environmental impacts (**Holwell**, **Jenkin**, **Smith** and ICS2).

Since REF2014, we have increased research income by 67% per FTE. Category A staff have published 691 refereed journal papers, attracting 12,862 citations. Of these papers, 24% are published in journals within the top 10% citation percentile (Scopus/SciVal). Our R&I activities include 219 publications mapping onto the UN's Sustainable Development Goal 'Climate Action' (111) and 'Life on Land' (108), significantly contributing to UoL's ranking in the top 3% in the Times Higher Education World Impact Rankings 2020.

Unit context and structure

UoA7 sits within the College of Science and Engineering. Our research is shaped by two College Research Themes: (1) **Environment** and (2) **Astronomy, Space and Earth Observation**. This has facilitated multidisciplinary engagement and collaborations drawing on diverse specialist knowledge. Since REF2014, the Geography and Geology Departments have merged to form the School of Geography, Geology and Environment to better realise our research ambition to create a vibrant community of researchers working in the Earth and Environmental Sciences with past, present and future perspectives. We have also strengthened the alignment of Earth observation (EO) scientists across the University, building on the inter-disciplinary co-ordination of EO at Leicester since its foundation in 1993.

The unit's research activity is organised functionally into three Research Groups (RGs): (1) **Evolution and Past Environments**; (2) **Solid Earth**; and (3) **Contemporary Environments** (Fig.1). The Groups operate as nuclei for research staff and students with related specialisms. Collaborative working has encouraged research output quality, funding success, and impact, significantly enhanced through staff mentoring, inclusive strategic discussions, and weekly discursive lab-groups and seminars. Our capability to employ an array of physical, chemical, and geological approaches to analyse the atmosphere, geosphere, and biosphere has been dramatically enhanced by these strategic developments.

Each RG houses a Research Centre, recognised by UoL as 'centres of research excellence'. The Centre for Palaeobiology is focused on delivery of agenda-setting palaeobiology research, especially on applying experimental and quantitative approaches to the fossil record. The Centre for Sustainable Resource Extraction carries out research to ensure security and supply of Earth resources to society, coupled with a substantial reduction in environmental footprint, through the development of technologies that will revolutionise the relevant industries. The Centre for Landscape and Climate Research (CLCR) delivers enhanced understanding of human-environment interactions using EO technologies to address pressing global challenges such as land use change, fire disturbance, deforestation, and forest and peatland degradation.

UoA7 also hosts the National Centre for Earth Observation (NCEO), a multiple-location NERC Research Centre, directed by **Remedios**. UoA7 staff in NCEO lead national, cross-HEI programmes in environmental observations, including carbon cycle (**Boesch**), EO methods and data (**Remedios**), UK Earth System Model and the NCEO Official Development Assistance Programme (**Balzter**). They provide membership of 8 international satellite mission advisory groups and science teams. Additionally, through the NCEO, the CLCR leads the Programme Coordination Team of the £10.5M UKRI Strategic Priorities Fund Landscape Decisions Programme. Thus, UoA7 boasts a large portfolio of research using EO techniques to address challenges ranging from global climate change to ecosystem change, land emissions, and impact of hazards.

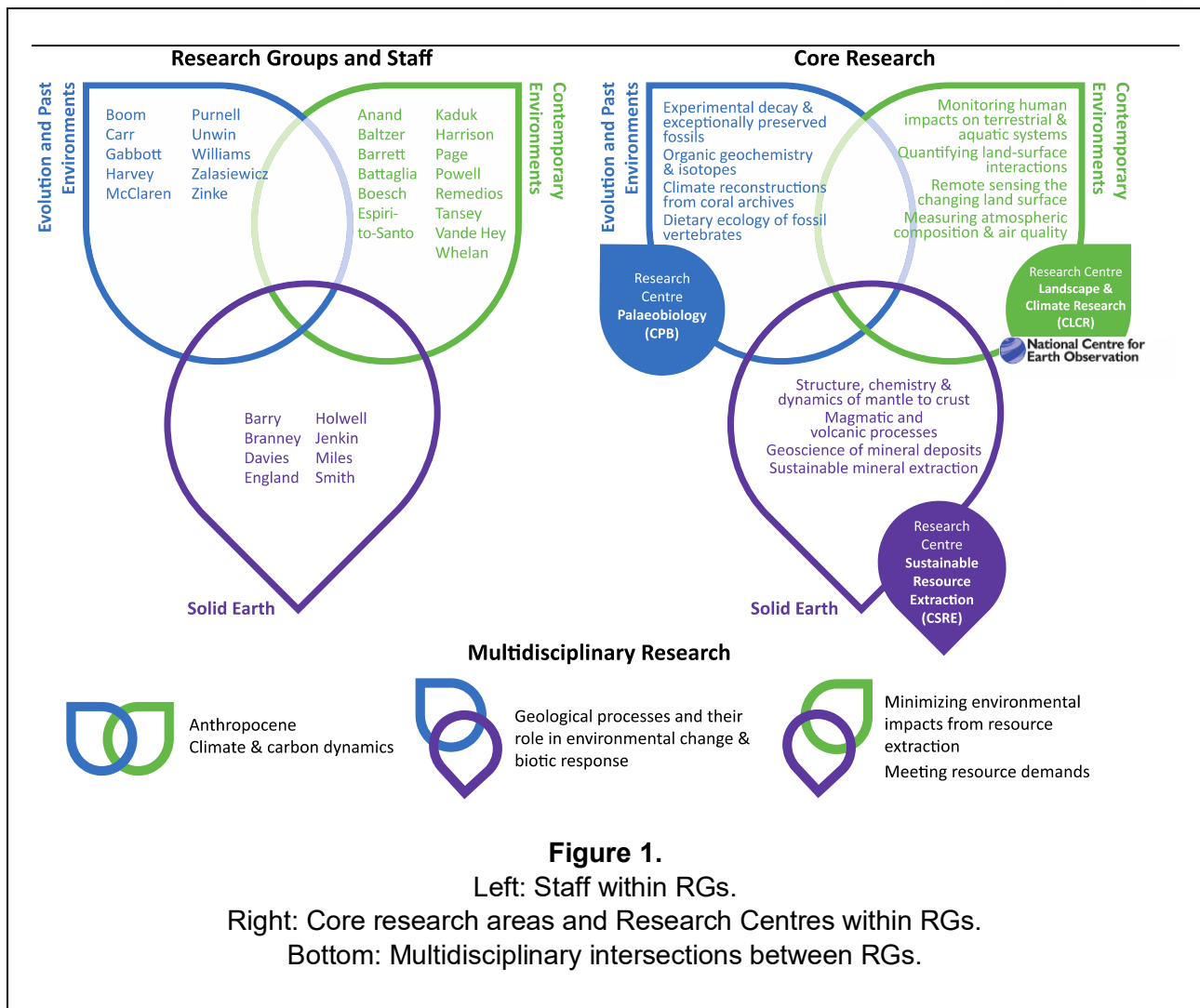


Figure 1.

Left: Staff within RGs.

Right: Core research areas and Research Centres within RGs.

Bottom: Multidisciplinary intersections between RGs.

Research and Impact Strategy

REF2014 aims. In REF2014, our future strategic priorities were to: maintain and develop our research groups; protect quality research time; and build collaborations across the University and with external organisations, including industry. We have both achieved and progressed these aims. The breadth of research expertise has enabled us to build on our existing research strengths and catalyse new and exciting research directions. We have protected research time, resulting in improved quality of outputs and grant capture (increase of 67% income per FTE since REF2014), recruitment of funded Independent Research Fellows (8-fold increase), PDRAs (a factor 2.8 increase) and PGR completions (an increase of 42% per FTE/year). We work with colleagues across the University, and our external reach and collaboration with industry has seen a significant step-change.

Vision and Strategy

Our vision throughout this cycle has been to support our researchers in the delivery of the best possible research via the provision of a supportive, dynamic, and flexible environment which stimulates and disseminates international and world-leading research that is: (a) discovery-led, addressing fundamental questions about the Earth, atmosphere, and biosphere, past and present, and; (b) challenge-led, developing solutions to the major problems of sustainability and stewardship of our planet, with an explicit goal of maximizing the impacts of our work.

The 8 guiding principles of our R&I strategy are to:

- (R1)** Build established areas of research excellence whilst nurturing emerging strength.
- (R2)** Promote, support, and grow multidisciplinary and interdisciplinary projects and collaborations, enabling research to move into new and fruitful areas and allow us, collectively, to respond to emergent challenges of environmental, industrial, and societal relevance.
- (R3)** Increase the impact of our research by developing strong links with industry and policy makers.
- (R4)** Recruit and retain outstanding academic staff to provide leadership and expertise, and nurture ECRs and future leaders.
- (R5)** Recruit high-quality PhD students and develop a community of well-rounded and highly employable researchers.
- (R6)** Maintain a diverse funding portfolio to underpin research and impact, by proactively engaging with funders via agenda-setting initiatives and supporting staff in their preparation of applications.
- (R7)** Maintain specialist facilities and equipment through institutional bids and overhead reinvestment.
- (R8)** Maximise global engagement with our research by embedding a culture of open science.

We provide evidence for how each of these principles is facilitated, and their effectiveness, throughout this statement.

Governance and integrity. The development and implementation of the unit's R&I strategy is the responsibility of the Research Committee, led by Director of Research (DoR). This includes: Head of School (HoS), REF lead and REF impact lead, Research Group leads, Postdoctoral and PhD student representatives, Research Centre heads, and PGR tutors. We adhere to institutional policy on research integrity (Institutional environment statement, section 2.7) and expect researchers to embed good practice in all aspects of their work, as outlined in the Concordat to Support Research Integrity. Performance, using data from output quality reviews, and grant applications is monitored in monthly meetings between the DoR, REF lead, HoS, and the College Dean of Research, as well as via annual performance development discussions (PDDs).

Open Research (R8). In addition to observing REF policy and institutional requirements (IES, 2.6), we have embedded a culture of open research. In Leicester's first Open Research Survey (2020), 100% of research staff in this UoA who responded believed there is value in anyone being able to access their research and 79% had actively made more of their research freely available and accessible since 2014. During the assessment period, 75% of our outputs were published open access, compared to the Russell Group average of 63% (SciVal). Many of our researchers are editors and/or on the editorial board of open-access peer-reviewed journals (e.g. **Baltzer, Kaduk and Tansey** for *Remote Sensing*; **Zinke and Purnell** for *Scientific Reports*), and we use open platforms such as Github, DRYAD, and Figshare. Data produced through NCEO programmes and other NERC-funded projects are available publicly on the NERC-STFC platform CEDA.

Approach to impact (R3)

Our research aims to influence policy to mitigate climate change and protect the environment, enhance industrial performance, and improve people's lives. The principal beneficiaries of our research are the public, the environment, natural resource and space industries, and UK and EU governments.

The mechanisms employed to deliver impact are:

1. *Multidisciplinary collaboration (R2)*. We recognise the benefits of a multidisciplinary approach to addressing social, environmental, and industrial challenges. A cornerstone of our impact strategy is EO, involving environmental scientists, chemists, and physicists. The work by **Boesch** and NCEO colleagues has significantly improved the accuracy and reliability of satellite-derived data for monitoring global emissions (ICS1). Their research has enabled international environmental and space programmes to provide governments with resources and recommendations to facilitate compliance with the Paris Agreement. **Boesch** et al are playing a leading role in the first ever purpose-built European CO₂ Monitoring satellite mission and were instrumental in devising a European operational system which can meet the political needs for monitoring and verification of carbon emissions.
2. *Provision of expert advice to policy-making bodies*. We recognise the value of translating evidence-based research into effective policy-making in support of improved environmental protections and action on climate change. **Page's** research (ICS3) on carbon-rich peatland ecosystems has shaped EU, USA, and Indonesian policies on peatland land uses and biofuels derived from palm oil, while also contributing to palm oil certification standards (RSPO). **Remedios** works closely with UK government in Defra and the UK Space Agency (UKSA): e.g. the UK international office for GEO and CEOS and across government on space sector initiatives and COP-26.
3. *Fostering sustainable relationships with industry partners*. This is a vital strand to our approach to knowledge exchange and enables us to tackle practical problems identified by industry. **Holwell's** research which has informed and generated strategies and mining procedures for mining and exploration companies in Greenland and Zambia (ICS2). By enabling these companies to accurately pinpoint ore resource, **Holwell's** research contributed to significant economic growth for these companies, increased employment in local regions and reduced environmental damage. **Tansey** is lead for EO innovation at the Leicester Innovation Hub (IES, 2.5). **Tansey** has been funded for three Innovate UK Energy Catalyst Round projects on renewable energy assessment in African countries. The EO teams have supported >130 companies in 10 years to understand and implement EO-based research and data sets (>50 based in the Midlands). Strategic support has been obtained through Leicester-led projects, including the East Midlands Centre of Excellence supported by the Satellite Applications Catapult, environmental fellows in the ERDF-funded Innovation Hub and the HEFCE-supported SPRINT programme.
4. *Impact leadership and support*. The UoA created a new post of Impact Lead (**Page**) who has facilitated liaison with policymakers and industry for the purpose of communicating UoA capability, as well as providing advice, training, and support to colleagues to improve impact planning (**R6**). In addition, we benefit greatly from the expertise and support provided by the University's Research Impact team and financial support from a dedicated Impact Development Fund. These activities have been underpinned by three NERC knowledge exchange fellowships (Johnson, Morgan, **Vande Hey**) and College- and University-level initiatives providing funding of impact projects.
5. *Public engagement*. We have orchestrated a comprehensive programme of community engagement activities that aim to engage with underrepresented groups. These include public lectures, festivals, and learning resources for school children to increase interest in geophysics and enhance understandings of environmental change from space.

Approach to multi- and interdisciplinarity (R2).

Meeting the challenges that society faces, and advancing our understanding of how our planet works, needs multidisciplinary and interdisciplinary research. We have achieved this by facilitating the interaction of staff to address environmental challenges, so that research is applied and translational. College Research Days are specifically aimed towards bringing staff together to strengthen our ability to take advantage of opportunities arising in the external environment that cross traditional discipline boundaries. For example, **Jenkin** and **Smith** are collaborating with colleagues in Chemistry with support from Argo Natural Resources Ltd (total £272k) to explore the potential of deep eutectic solvents as green replacements for harmful chemicals in metal recovery from ores. We are collaborating with social sciences to develop scientifically, socially, and culturally-informed investigations in resource utilisation. For example, **Page** is collaborating with Upton (UoA14) on the SUSTAINPEAT project, overcoming barriers to sustainable livelihoods and environments in smallholder agricultural systems on tropical peatland (BBSRC, £200k to UoL).

We receive institutional support through the Leicester Institute for Advanced Studies (LIAS), launched in 2016 with the specific aim of promoting interdisciplinary research (IES, 2.2). Emerging areas of research are supported by smaller-scale seed-corn funding that target 'grand challenges'. This funding facilitates the assembly of researchers to enable faster development of pioneering research ideas to address future funding calls. UoA7-led projects include 'Anticipating and Avoiding Unintended Consequences of Remote Sensing Applications' (Johnson) and 'Earth System Plastics' (**Gabbott**). The latter was submitted as a Strategic Programme Idea and fed into a UKRI Collective GCRF Fund call (£20M) 'Reducing the Impacts of Plastic Waste in Developing Countries'.

Achievements by research group (R1)

Evolution and Past Environments is concerned with reconstructing the environment and evolution of life from 'deep time' (Palaeozoic through Cenozoic) to the Anthropocene. The group aims to enhance our knowledge of past environments, past climates, and the processes and patterns of the evolution of life, and further extends this knowledge to assess the current and future state of the Earth. The group has a strong track record of success in targeting journals with the highest rejection rates and citation metrics: for example, of 241 outputs published in this cycle, 49.8% are published in journals within the top 10% (citescore), and 27.4% are among the top 10% most cited outputs worldwide (Scopus/SciVal).

Headline achievements include:

1. Analysis of evolutionary, ecological, and environmental transitions (e.g. **Harvey** in Hearing et al. 2018, *Science Advances*; **Harvey** and Butterfield 2017 *Nature Ecol. Evol*; **Purnell** in Gill et al. 2014 *Nature*; **Purnell** in Bestwick et al. 2020, *Nature Comms*).
2. Novel approaches to phylogenetic placement of enigmatic organisms (**Gabbott, Purnell** in Clements et al. 2017, *Nature*), and analysis of early vertebrate vision (**Gabbott, Purnell** et al. 2016, *Proc. Roy. Soc. B.*).
3. Catalyzed the development of the Anthropocene concept via world-leading scientific and philosophical contributions to its definition, starting point and impacts (e.g. **Williams** in Waters et al. 2016 *Science* (744 citations, FWCI 15.12)).
4. Palaeoclimate reconstructions derived from ancient and modern archives using a variety of innovative techniques (e.g. isotopes, trace elements, biomarkers, OLS dating) to reveal details about how the Earth System works, including ice sheets (**Williams** in Hillenbrand et al. 2017, *Nature*), coral reefs (**Zinke** in Abram et al. 2016, *Nature*, FWCI 5.81; **Zinke** in Neukom et al. 2014, *Nature Climate Change*, FWCI 10.27; **Zinke** et al.

2015, *Nature Comms*) and rainforests (**Boom** in van der Sleen et al. 2015 *Nature Geoscience*, 221 SciVal citations, FWCI 16.84).

Solid Earth is predominantly concerned with Earth System processes, including the structure, chemistry, and dynamics of the planet, from mantle to crust. The group studies processes that range from catastrophic events such as volcanic eruptions and extraterrestrial impactors through to techniques for sustainable extraction of mineral resources.

Headline achievements include:

1. New and fundamental insights into crustal dynamics and the nature of volcanic super-eruptions (**Branney** in Knott et al. 2016; 2020, *Geology*), meteorite impacts (leadership by **Branney** and **Barry** of a multinational NERC Discovery Science project) and the formation of mineral deposits (NERC Highlight Topic consortium 'Arc Magmas to Ore Systems (FAMOS)' (UoL Cols: **Smith, Holwell, Miles, Barry, Knott, Jenkin; R6**)) which boasts collaborators from research, industrial and international organisations, with £2.9M recovered from the funders across the consortium).
2. Powerful new models of ore-forming processes (e.g. **Smith, Jenkin, Holwell** in Keith et al., *Ore Geology Reviews*; **Smith, Jenkin** et al., 2017 *Ore Geology Reviews*; **Holwell, Smith** et al. 2019 *Nature Comms*; **Smith** 2014 *Nature Comms*; **Holwell** in Blanks et al. 2020 *Nature Comms*) and leadership in critical raw materials (**Smith, Holwell** and **Jenkin** led the NERC funded TeaSe consortium (£843k), focusing on sources and cycling of tellurium and selenium).
3. Innovation of more sustainable exploration and extraction of mineral resources, and new ways of processing metal ores to reduce environmental and social impacts of resource exploitation (e.g. **Jenkin** in Anggara et al. 2019 *Green Chemistry*; **Jenkin** et al. 2015, *Minerals Engineering*).

Contemporary Environments deals with observations and understandings of environmental processes on both a fundamental level and in terms of the impacts of human activities on our environment. The group encompasses the work of NCEO and the CLCR, delivering world-class science in satellite-based remote sensing of deforestation, land use change, meteorology, climate change, and greenhouse gas inventories (funded by, *inter alia*, ESA, European Union, European Environment Agency, UKSA, Royal Society, NERC and GCRF).

Headline achievements include:

1. New insights into our understanding of the terrestrial carbon cycle (including fire, forest degradation and loss, and peatland drainage) including the dynamic interactions between the drivers for and consequences of land use change, and quantification of the effects of drought induced wildfires on the carbon balance (**Espirito-Santo** in Withey et al. 2018, *Phil Trans. R. Soc. B*; **Boesch** in Parker et al. 2016 *Atmos. Chem. Phys*).
2. Fundamental new insights into the amount of carbon stored in the world's peatlands, their contributions to global GHG emissions and role in natural climate solutions (e.g. **Page** in Dargie et al. 2017, *Nature*, FWCI 10.34, cited >250 times; **Page** in Leifeld et al. 2019, *Nature Climate Change*; **Page** in Goldstein et al. 2020, *Nature Climate Change*), new estimates of forest biomass and carbon stocks (e.g. **Balzter, Tansey** in **Rodríguez-Veiga** et al. 2016, *Remote Sensing of Environ*) and deeper insights into the tropical carbon cycle (**Boesch** in Palmer et al. 2020, *Nature*).

3. Improved estimates of greenhouse gas fluxes and emissions (e.g. **Boesch** in Ganesan et al. 2017 *Nature Comms* and Wang et al. 2020 *Nature*), new insights into the behaviour of environmental pollutants (**Whelan** in Krogseth et al. 2017 *Env. Sci. & Tech*; **Harrison** in Hossaini et al. 2015; **Harrison** et al. 2016 *Atmos. Chem. Phys*; **Harrison** in Chipperfield et al. 2016, *Atmos. Chem. Phys.*), development of new retrieval algorithms and application of novel tools for rigorous climate-quality, remote sensing of land surface temperatures (LSTs e.g. **Ghent** et al. 2017; **Ghent** and **Remedios** in Dodd et al. 2019 *JGR Atmospheres*; **Remedios** and **Ghent** in Good et al. 2017 *JGR Atmospheres*) and tropospheric air quality monitoring (e.g. NO₂ and PM_{2.5}; **Vande Hey** in Lin et al. 2020 *Atmospheric Environment*).

Future research and impact plans

Through our guiding principles we will continue to provide a supportive and inspiring research environment, delivering high-quality research in areas of existing strength and maintaining agility to take advantage of arising opportunities. Our four core strategic objectives for the next five years are:

1. *To support and build discovery-led science in our priority areas*, generating world-leading and agenda-setting outputs and pushing the boundaries of knowledge. These discoveries will provide a platform for exciting public engagement. Research areas of particular importance are: novel and quantitative analyses in palaeobiology; fundamental structural, geochemical and mineralogical understanding of mineral deposits and their formation, and of impact craters and super-eruptions; and improving our understanding of planetary responses to environmental change, including global surface temperature and GHG fluctuations, terrestrial ecosystem dynamics, carbon stocks and climatic feedbacks.
2. *To engage with the world's grand challenges via interdisciplinary research* to foster sustainable development under climate change and transition to a low-carbon future. We are increasingly working with colleagues beyond our traditional academic siloes to seek solutions for challenging problems. E.g. **Page** is part of a new interdisciplinary NERC GCRF project (£739k to UoL) with social science colleagues to deliver practical solutions to protect health, livelihoods, biodiversity and climate in Indonesia. We aim to further engage with challenge-led research agendas through our strengths in palaeontology, stratigraphy, and taphonomy to understand current issues (such as the spread and impact of invasive species) and to help find solutions. E.g. **Williams** has received Institutional support to lead an interdisciplinary Research Network 'Reimagining the Homogenocene' which aims to improve our understanding of ecological resilience in human and nonhuman contexts; this will be a £10M Leverhulme Research Centre bid.
3. *To grow and diversify partnerships and collaborations with non-academic stakeholders* in order to maximize our impact in three specific areas: **(1) Terrestrial carbon dynamics**. We will continue to strengthen new and existing international partnerships in southeast Asia (e.g. Peatland Restoration Agency and Ministry of Environment and Forestry, Indonesia) and the UK (e.g. Defra, BEIS) which have underpinned recent impact (ICS3), and in South America (Brazilian Agricultural Research Corporation (EMBRAPA) linked to Brazilian Ministry of Agriculture (**Espirito-Santo**)). **(2) The sustainability of resource supply** to support low-carbon technologies, such as solar panels and batteries. We will inform and influence UK government policy (**Smith's** role with the Parliamentary Office of

Science and Technology) and engage with the mining and metals processing industries to reduce environmental impacts and drive a more sustainable future. This work starts now as part of a *Circular Economy Centre in Technology Metals* for which UoL will receive £950k (**Jenkin** and **Smith**). **(3) Public engagement.** We will build wider engagement at national level, working with our sporting partners (Leicester City Football Club and the National Youth Agency) and the National Space Centre, focusing particularly on big environmental science challenges, such as upcoming COP-26 and activities within **Branney's** asteroid impact project.

4. *To enhance our capacity and impact in applications of EO.* We will build on our substantial strengths in carbon and climate data, forestry, and atmosphere composition whilst engaging in new related science with innovative applications; e.g., the latest satellite missions. Areas of focus will include: vegetation fluorescence and carbon, urban environments, fire emissions and long-term records, climate services, minerals exploration, and peatland resilience. A key initiative in this area is Space Park Leicester (IES 2.4, 4.4)—completion of phase 1 will bring together all our EO work in one building for the first time. Of the £100M+ invested in SPL to date, ~£52M is being directed towards EO research and activities, including the Manufacturing, Engineering, Technology and Earth Observation Research Centre. Once established, our EO and environmental staff will undertake cutting-edge core research and will deliver pioneering academic-industry co-development, with commercial companies working and co-locating alongside the best researchers to feed excellent EO science directly into services and inform government policy. We have established a baseline EO partnership of 12 companies in this new venture, from which we will support a network of SMEs.

2. People

Research Staff (R4)

Overview

We are submitting 31.85 FTE staff to REF2021 (Table 1). Since REF2014, there have been 5 internal promotions to Associate Professor [**Carr, Barrett, Holwell, McLaren, Smith**] and 7 to Professor [**Zalasiewicz, Branney, Gabbott, Tansey, Jenkin, Boesch, Whelan**]. We have a strong track record in securing grants for postdoctoral researchers, including 65 PDRAs and 9 Independent Fellows comprising two Royal Society International Newton Fellows, McCoy and Mendes de Moura; three European Space Agency (ESA) Fellowships to **Anand, Trent, and Parker**; a Daphne Jackson Fellow, Greenfield; and three NERC KE Fellowships, **Vande Hey, Johnson, and Morgan**.

Our research activity is supported by 2 teaching fellows, 4 teaching-focused academics, and 2 cartographers who produce graphics for outputs and wider engagement.

	<i>Total</i>
Lecturers	6
Associate Professors	11
Professors	14
PDRAs	65*
Independent Research Fellows	2 (9*)

Table 1: Composition of academic staff in UoA7.

**Includes past PDRAs and Fellows.*

Staffing strategy and development.

Our collective strength thrives in a supportive, diverse, and inclusive environment. This is at the heart of how we seek to recruit and nurture staff at all levels. Our aim is to provide the same support and opportunities to *all* staff. Our staffing and staff development strategy is built around the following principles:

1. **Retain talented staff by providing development opportunities, as outlined in the Concordat to Support the Career Development of Researchers.** During the REF2021 cycle, we have promoted staff who joined as ECRs to Professor (**Gabbott, Tansey, Jenkin**) and to Associate Professor (**Barrett, Carr, Holwell, McLaren, Smith**). People stay where they are happy, motivated, and supported. Our retention strategy is based on facilitating success, creating clear pathways for staff development, and providing a supportive, collegial and stimulating working environment. The University allows a fraction of grant overhead to be shared between Schools and PIs, facilitating further research investment, dissemination activities, PhD co-sponsorship, workshops and equipment procurement. To make time for research many staff have teaching grouped into one semester, and we encourage study leave (typically one semester in seven).
2. **Recruit new colleagues at all career stages, targeting appointments that will enhance our expertise in areas of strategic importance.** During the REF period, we have made 9 new appointments, including 4 research-led appointments in key areas identified for strategic development (**R1**): Prof. **Zinke** (Royal Society Wolfson Fellow) is a quantitative palaeoclimatologist, with a focus on tropical marine coral reef ecosystems. Associate Professor **Espirito-Santo** is a landscape ecologist focusing on post-disturbance changes to forest structure, principally using EO, in the Brazilian Amazon. His appointment reinforces our remote sensing research in land cover change, ecosystem dynamics and biogeochemical cycles. Lecturer **Miles** investigates crustal processes with applications in sustainable mineral exploration and supply of resources critical to renewable energy. **Vande Hey** joined us as a PDRA in 2013 and then won an independent NERC KE fellowship on air pollution and health. This was enhanced by an internally-managed Wellcome Trust Institutional Strategic Support Fund interdisciplinary fellowship. He was appointed to an interdisciplinary Lectureship in environment and health in 2018.
3. **Create a working environment that motivates and supports all staff to develop their career.** All staff have an annual Performance Development Discussion (PDD) with a senior colleague, which includes review and planning of research and training

needs. PDD reports are reviewed by the HoS to identify candidates for promotion and to assess the need for interventions (e.g. workload adjustments). Our weekly 'lab groups' are sub-sets of our three research groups and include Category A staff, PDRAs, PhD students, and technicians—these have significantly enhanced our research environment, from discussion of 'big questions' to skills-based topics. Joint lab-group meetings are directed to identify and instigate multidisciplinary research ideas.

Staff on Grade 9 and above can access the University's Future Leaders Programme which helps colleagues define their strengths, motivations, and leadership skills. UoA7 staff who completed this programme have gone on successful leadership roles, including: **Davies**, Head of School GGE and Head of College of Science and Engineering (CSE); **Purnell**, Dean of Research CSE; **Whelan**, Director of Research; **England**, former Head of Geology and Director of SEIS-UK; **Tansey**, former Head of Geography. Additional high profile leadership roles held at College include: Director Advanced Microscopy Facility (**Gabbott**), Director of PGR (**Williams**), Research Impact lead (**Page**), Enterprise lead (**Tansey**) and Director of NCEO (**Remedios**).

4. **Provide additional support for early career researchers (ECRs).** In addition to institutional support and annual PDDs, ECRs go through an induction programme and have regular probation meetings. We have ECR representatives on the Research Committee, Athena Swan and EDI Committees, and a dedicated Research Staff Advisory Group to support the professional development of postdoctoral staff. In addition, ECRs have individual mentors to discuss research and impact plans and help with grant and output writing. Furthermore, **Davies** and Morgan organised 3 successful, international, CPD-accredited Summer Schools (2016-2019, 108 participants, 70 institutions, 14 countries) focused on enabling ECRs to use physical properties data in their research.

Visiting scholars: We have been visited by researchers from all over the world (Fig.2). E.g.: **Tansey** has hosted >10 visits from academics, researchers and students from China Agricultural University and Peking University, as part of exchange programmes supported by the Royal Society and the Chinese State Administration of Foreign Experts Affairs. This collaboration resulted in 10 papers.

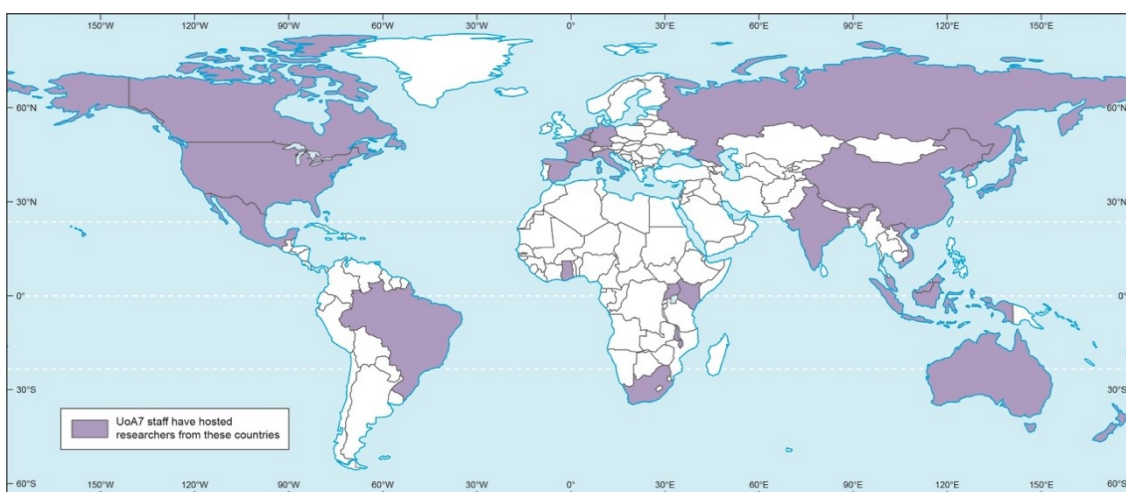


Figure 2: Global distribution of visiting scholars

Research Students (R5)

Recruitment and studentships. We recognise that research students are essential to our research environment. Over the REF period, we have had 84 doctoral completions—representing a doubling of completions per year and a 42% increase in completions per FTE per year since REF2014. Funding for studentships over the REF period has come from an increasingly diverse range of sources, including 21 competitively awarded NERC-CENTA projects, 2 NERC iCASE awards, and 4 highly competitive college-funded studentships. We were also lead organisation (PI **Balzter**) for GIONET, a European Marie Curie Centre of Excellence for Earth Observation Research Training, which supported 10 Leicester PhD students. In the 2018 NERC Doctoral Training Partnership (DTP2) competition, the Central England NERC Training Alliance (CENTA), of which we held the Deputy Directorship (**Purnell**), was awarded 18 notional studentships annually—the highest in the UK for NERC DTPs. PGR funding has also been obtained from a number of other international, governmental, and industrial sources, including: SIOPACT (Germany DFG), the Petroleum Technology Development Fund, ESA, Consolidated Nickel Mines, Anglian Water, the Royal Thai Embassy, the Iraqi Ministry of Higher Education, King Abdulaziz University, CASP, and the Chinese Science Council. Furthermore, MPhil students have been recruited using ERDF funds through the Leicester Innovation Hub (LIH), and are supervised by an academic, an Innovation Fellow from the LIH, and a representative from industry.

Training, support, and monitoring. Students have meetings with their supervisors (2 internal) at least once a month, which are recorded to monitor engagement and progress. PGRs complete a training needs analysis and follow a tailored training plan. Progress is assessed by an independent panel at 3 and 9 months, and then annually until the viva. Research students are supported within lab groups which provide a forum for them to present their work, debate scientific developments, and broaden their perspectives. They are also actively encouraged to organise meetings and workshops, support national and international conferences, and take advantage of our extensive international networks.

The PGR training programme is consistent with the Researcher Development Framework. Central training is coordinated by the University's Doctoral College (IES, 3.2). The 2019 Postgraduate Research Experience Survey indicated that 91% of PGRs believe that their training develops their skills in applying appropriate research methodologies, tools, and techniques and 88% agreed that it allows them to increasingly manage their own professional development.

PGR achievements. We celebrate PGR success stories via a monthly newsletter, social media, and on the UoL website. Our research students are actively encouraged to publish, helping them to secure postdoctoral positions and to apply for independent fellowships. For example, Clements et al. 2016 presented novel evidence that the enigmatic fossil 'Tully Monster' had a vertebrate affinity (*Nature*, 2016: 99th percentile for online activity of all tracked articles of similar age; Altmetric). Clements secured a Leverhulme Fellowship at Birmingham University. Many research students have very visible media profiles—in part due to PGR media engagement training run by **Gabbott** (British Science Association Media Fellow 2017). For example, a paper on supervolcanoes based on Knott's PhD (*Geology*, 2020) attracted stories and interviews in *Scientific American*, *USA Today*, the *NY Times*, the *Express*, and the *Mail*.

There is an annual PGR Research Day, with prizes awarded to the best talks, to support attendance at an international conference of their choice. Several monetary awards are available annually to support PGR research and public engagement.

Our research culture encourages PGR students to engage with the wider scientific community. Several have won plaudits, awards, and recognition, both nationally and internationally. Select examples include: hosting the Progressive Palaeontology Annual Conference 2017 (Bestwick); a Society of Economic Geologists Graduate Fellowship of \$10k, sponsored by Anglo American (Ward); a Parliamentary Office for Science and Technology POST Fellowship on remote sensing and machine learning, 2020 (Essen); a UKRI/NERC Science Policy Fellowship at the POST (Essen); winner of the UK's Remote Sensing and Photogrammetry Society Student Award for the best PhD thesis submitted in 2017 (Rodriguez-Veiga); recipient of the Geological Society's 2020 Lyell Fund (Hearing); winner of the President's Prize at the Palaeontological Association 2017 Meeting (Bestwick).

Next destination. Since REF2014, 40% of our 84 PGR graduates have progressed to academic positions in the UK and overseas, including lectureships and postdoctoral roles. 39% of graduates have progressed to industry posts, including Equinor, Airbus Defence and Space-Intelligence, the Asian Development Bank, Scotgold Resources, COREX, and Point4; 10% are in government-funded institutes, including CEH, BGS, the Met Office, and the Environment Agency. The remaining graduates are teachers (5%), work for Charities (2% e.g. Project Leader, Borneo Orangutan Survival Foundation), or are in academic professional support.

Equality, Diversity, and Inclusion (EDI)

We have a strong and genuine commitment to EDI. In addition to implementing institutional strategy and policy (IES, 3.1), we have a dedicated EDI officer (Matulis) who works alongside Athena Swan officers (**Balzter, Barrett**). They play an important role in maintaining a high profile for EDI issues by, for example, running workshops on topics such as intersectionality, overcoming challenges for women in fieldwork, and LGBT issues. There is currently a large group of LGBTQ+ academics and students within the Unit who meet informally and provide a supportive environment.

The School is preparing a combined application for a Bronze Athena SWAN Award, to be submitted in 2021. Currently, 18% of submitted staff are women (21% of Professors, 18% of Associate Professors, and 17% of Lecturers). We recognise that women are underrepresented at all levels. To tackle gender inequality, we are actively promoting the visibility of female role models by, for example, ensuring female staff are supported to attend institutional and national leadership programmes, such as the Aurora Women's Leadership Programme (**Gabbott**: now REF lead). In this REF cycle, there has been an increased number of female PDRAs: 5/6 of the IODP research staff and a NERC IODP Knowledge Exchange Fellow (Morgan, 2014-2017) and all of research staff employed by SEIS-UK are women. Our challenge is to transform our culture and environment to attract, welcome, and retain applicants from women and other under-represented groups in permanent positions.

We acknowledge that we need to improve our BAME representation. Currently, 9.1% of REF-eligible staff are BAME and 7.7% of staff at Professorial level are BAME. In line with the University's commitment to improve the representation and progression of minority staff (IES, 3.1), we have already begun to drive forward race equality initiatives, including attracting a diverse range of external speakers to internal events to promote a positive and inclusive culture.

We are encouraged by the increasing diversity of our PhD community and what we hope indicates a snapshot of the profile of our unit in the future. During the REF period, 62% of our PhD cohort were female and 36% were BAME.

We are submitting all eligible staff in our REF return. UoL's REF Code of Practice specifies how our REF return has been compiled with due regard to EDI. In advance of this, we ensured a diverse mix of staff were involved in output quality review. We have a supportive process in place for declaring staff individual circumstances in relation to our REF submission, guided by our EDI Officer (Matulis) and University's EDI team. We have robust support structures in place so that even staff facing substantial challenges have been able to produce outputs for REF.

3. Income, infrastructure and facilities

Income (R6)

During the REF2021 period, our average research income per FTE has increased by 67%, from £87k FTE/year (total income ~£2M/year) in REF2014 to £145k FTE/year (total income ~£4.63M/year) for REF2021. UoL is among the top UK institutions in terms of NERC Science Budget expenditure (e.g. 9th in 16-17 NERC Annual Report, the most recent available). Furthermore, our portfolio has diversified (Fig.3). Our success has been underpinned by institutional support for capturing external awards (IES, 4), including the formation of Funder Groups (which provide peer-review and mentoring for grant applications), internal pump-priming schemes, and a proactive strategy to influence funder priorities. For example, we led the promotion of a NERC Highlight Topic on raw material demands of a green transition via the NERC SOS Minerals expert group and contributed to others on Copper and Lithium (**Smith**). These culminated in funded projects: **Smith, Jenkin, Barry, Miles, and Holwell** are Col's in FAMOS (From Arc Magmas to Ores: £238k to UoL) and we led CUBES (Copper Basin Exploration Science in the Central African Copperbelt: £338k; **England and Holwell**).

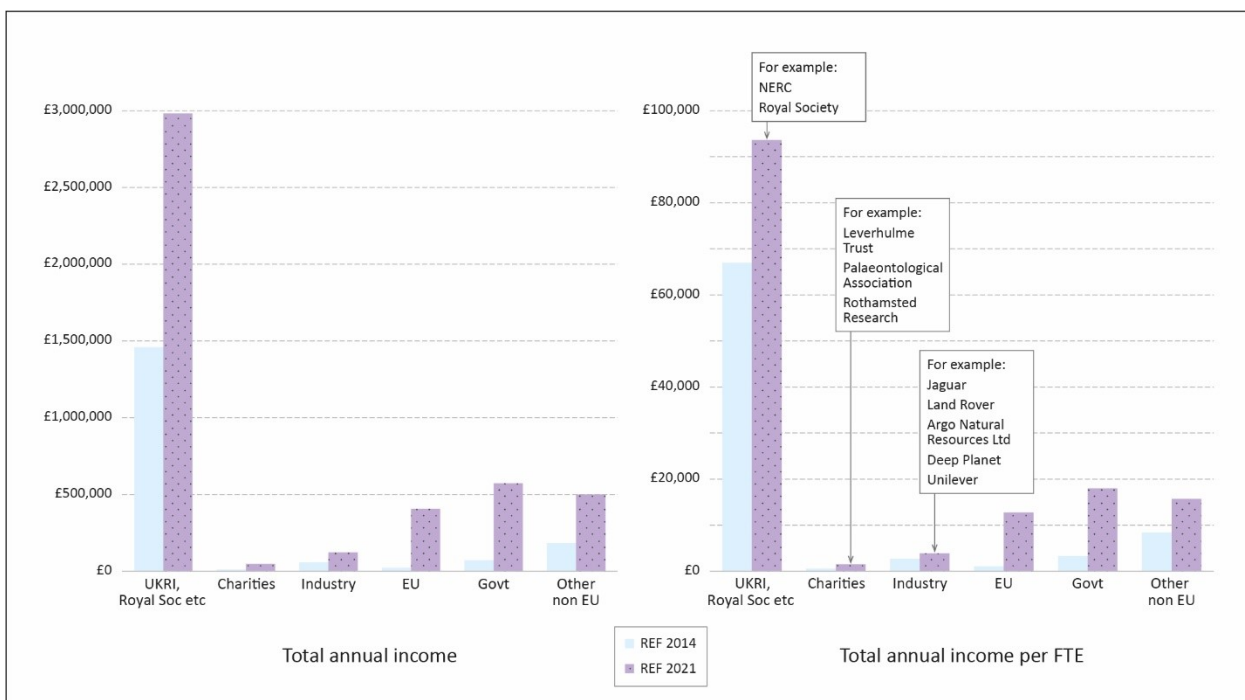


Figure 3: Funding in REF2014 compared to REF2021.

Our strength in earth observation has resulted in a number of high-profile grants. Key national funding has come through NCEO (£4.8M, **Remedios**, NERC) including long-term science, UK Earth System Model evaluation, the NCEO ODA programme, strategic greenhouse gas projects such as GAUGE (£364k, **Boesch**, NERC) and the UKSA-CNES Bilateral Carbon Mission Support Study (£480k, **Boesch**, UKSA). International awards include Copernicus

contracts to provide UK expertise, for example, in the Sentinel-3 Mission Performance Centre (£783k, **Ghent**, ESA); Copernicus land monitoring services to develop a new CORINE land cover map (£676k, **Balzter**, European Environment Agency); and leading projects to derive data for Essential Climate Variables including land surface temperature LSTs (£304k, **Ghent**, ESA ESRIN) and fire disturbance (£289k, **Tansey**, ESA Climate Change Initiative: CCI).

We have made substantial progress in securing challenge-led funding germane to our goal of tackling environmental challenges, for example: to help protect and restore up to 300M hectares of tropical forests through advanced applications of satellite data in the Forests 2020 programme (£1.3M to UoL, **Balzter**, UKSA). We are also making significant contributions to a NERC Large Grant CongoPeat (£149k to UoL, **Page**, **Boom**), investigating the developmental history and function of the vast peatland in the Congo Basin (30 Gtonnes of stored carbon: **Page** in Dargie et al., 2017 Nature). We are also investigating how the tropical oceans regulate our climate and to what extent global warming has modified natural cycles (£236k, **Zinke**, Royal Society Wolfson Fellowship).

We have secured challenge-led funding relating to our strengths in the Green Economy and, specifically, the location and extraction of minerals for sustainable development. For example, in the TEASE project (Tellurium and Selenium Cycling and Supply) we are investigating the sustainable supply of strategic metals for solar panels (£843k to UoL, **Smith**, **Holwell** and **Jenkin**, NERC).

We have also been successful in securing funding for fundamental science aligned to existing core strengths. For example, we led NERC Discovery Science projects on Siberian forest recovery from wildfire (£378k, **Barrett**) and on catastrophic asteroid impact cratering (£600k, **Branney** and **Barry**).

We have succeeded in developing stronger links with industry and policy makers to make meaningful impact (see Section 4; **R3**). For example, we have been awarded three Innovate UK projects (e.g. to explore micro hydro-power and crop waste residues as biofuels in Africa: £191k, **Tansey**) and funding from Anglo Operations to develop a model for world's largest Ni-PGE deposit in South Africa (£319k, **Holwell**). Our engagement with policy makers has led to a number of successes. Notably, we were appointed as the Programme Co-ordination Team for the UKRI Landscape Decisions Programme, managing the integration of 59 projects to deliver better evidence-based land use decisions and liaising with several government, business, and land-management stakeholders (£739k, **Balzter**, UKRI). We have supplied EO expertise to support the UKSA and Defra in inter-governmental and space agency bodies (£128k, **Remedios**, UKSA/Defra); and we have worked with industry to use satellite remote sensing to assess peatland degradation in SE Asia in the PASSES project (£183k, **Page**, UKSA).

Lastly, we have received ~£396k of income in-kind from UKRI, including 6 awards for NERC Isotope Geosciences, Community Support and Radiocarbon Facilities, GEF, and the NERC Ion Microprobe.

Facilities and Infrastructure (R7)

All UoA7 staff have individual offices with access to High Performance Computing (IES, 4.3) and specialised software. Laboratories are staffed by 8 experienced technicians with specialist expertise (e.g. in thin-section preparation, XRF, ICP-MS, electron-microscopy, and GC-MS). This support significantly enhances our research capability. Our state-of-the art facilities and equipment base is exceptional and has received substantial strategic investment over this

REF period, both externally and via the University's internal competitive Research Equipment Infrastructure Fund (REIF) which has funded £1.14M equipment in this cycle.

Specialist infrastructure, facilities, and equipment

The Unit hosts two major NERC capabilities (NCEO and GEF-L) and the International Ocean Discovery Program (IODP). **NCEO** has over 130 affiliated scientists distributed across leading UK universities and research organisations. Working strategically with space agencies and supported by NERC national capability funds, it provides the UK with core expertise in EO science, data sets, and model evaluation which underpins wider activities in Earth System research. Leicester-based NCEO staff play significant roles in the preparation of internationally-recognised data products (e.g. the Climate Change Initiative LST data) and use these to gain important Earth System insights (e.g. global landscape and forest carbon change, precipitation dynamics, greenhouse gas emissions, atmospheric chemistry and radiation balance).

NERC's Geophysical Equipment Facility (Leicester) is delivered by SEIS-UK. Led by **England**, it provides equipment, expertise and support for land based seismology. Its instrumentation and research support underpins the quality of seismic data acquired by the UK's seismological community, including researchers in the Unit, and it ensures that the data are freely available internationally. The **IODP** group (led by **Davies**) has a pivotal role within the European Consortium for Ocean Research Drilling (ECORD) Science Operator, providing high-level support for drilling expeditions, giving us visibility and influence in a range of cutting-edge scientific projects.

We have well-equipped laboratories with in-house capability for most standard analyses of rock, soil, and water samples. In particular, **petrology, mineral, rock and fossil analyses suite** enables a range of fundamental in-house analyses, including XRF, XRD, microCT, Environmental chamber SEM, and (Laser Ablation) ICP-MS. Additionally, REIF has funded a state-of-the-art Zeiss FEG-SEM with microXRF, WDS, 2 EDS, and cathodoluminescence with Mineralogic software (£700k). This configuration is unique in the world and provides unparalleled spatial quantitative geochemical analyses of rock and fossil specimens. Our researchers have access to the £4M Advanced Microscopy Facility (Director **Gabbott**) comprising several state-of-the-art Electron Microscopes (including FiB and TEM). Our ICP-MS facility provides critical support for projects, such as the catastrophic impact cratering project (**Branney** and **Barry**).

Our thin section laboratory is one of only four HE-based micromorphology labs in England (£320k equipment plus refurbishment costs). We also have the UK's only dental microwear texture lab (e.g. **Purnell** in Gill et al. 2014; *Nature*).

Our **organic analytical chemistry and stable isotope analysis laboratory** is equipped for novel compound-specific stable isotope analysis for accurate analysis of stable isotopes in biological and geological materials. Instruments for isotope Ratio MS, include a CDS Pyroprobe 1000 (for kerogen analysis) and a Thermo ISQ MS and Trace 1310 GC hyphenated with a Delta V Plus Isotope Ratio MS and Solid Phase Micro Extraction. This was funded by REIF (£248k) and allows ΔD to be determined on individual biomarker compounds (**Boom** in van der Sleen et al., 2015 *Nature Geoscience*, FWCI 16.84; **Boom** in Brienen et al., 2016, *Nature Comms*). It has also supported awards from NERC (**Boom, Page**: Seedcorn and 'Congo Peat' Large Grant), our contribution to an ERC project on environmental change in southern Africa using isotope analysis of rock hyrax middens (**Boom, Carr** in Chase et al., 2019 *Geology*, FWCI 6.04), and a Royal Society Wolfson Fellowship (**Zinke**). New research examining environmental plastic dynamics (e.g. **Gabbott, Boom**) has been supported by a FTIR Focal Plane Array chemical imaging microscope (REIF, £188k).

Our **Geochronology laboratory** employs a Risoe DA 20 TL/OSL reader with single grain laser attachment, Riso GM25-5A Beta counter, and portable field gamma spectrometer, housed within a bespoke analysis suite for estimation of sediment burial age (e.g. OLS dating). New insights from OLS dating have provided the first and only complete climate record (high resolution 50K years) for Namib Desert climate evolution (e.g. **Carr et al.**, 2016 *Quaternary Research*).

Geophysical and meteorological equipment includes a containerised Petrophysics Lab housing a Multi-Sensor Core Logger, Thermal Conductivity probes and a Discrete P-wave Analyser. Research and operations are supported by bespoke industry licenses for academic use, e.g. Kingdom Suite, Schlumberger's Petrel, and Techlog for seismic interpretation and mapping of wellbore data and Haliburton's SeisSpace for seismic reflection data processing. We access the SEIS-UK catalogue, and have field equipment and software for onshore recording of earthquakes and controlled seismic sources along with a range of near-surface geophysical surveying equipment. We deploy eddy covariance flux towers for measuring land surface-atmosphere trace gas exchanges on lowland deep and wasted peatlands in the UK (**Kaduk** and **Page** funded by Defra).

In EO, we have access to state-of-the-art facilities, such as clean rooms and dark labs, to develop, calibrate, test, and maintain remote sensing instrumentation, which are either used for field deployment or to demonstrate new technology for future space missions. This includes a network of radiometers for LST, a portable greenhouse gas column instrument (currently deployed to Uganda with the NERC MOYA project), a series of airborne instruments (GHOST greenhouse gas spectrometer, NO₂ mapper, and HAPI NO₂ imager), a state of the art terrestrial laser scanner (which can be used for groundtruthing EO data) and an ASD FieldSpec Handheld portable spectroradiometer for observations of reflectance, radiance, and irradiance spectra on the ground.

4. Collaboration and contribution to the research base, economy and society

Since REF2014, we have been involved with >160 national and international research collaborations across academia, the public sector, and industry—with 148 commercial contracts and 7 Technology applications. We have consolidated existing external partnerships and developed many new ones as a consequence of our new shape, size, and strategy (**R1, 2, 3**). Overall, the unit has brought in >£21.9M of Higher Education Business and Community Interaction relevant income from contract research, consultancy and commercial and analytical services (£98k FTE/year).

External collaborators include multinational companies (e.g. Anglo American, Newmont, Zeiss, Unilever, Reckitt Benckiser, Astra Zeneca, Dow Corning, Airbus, TAS UK, Telespazio, CGI,), SMEs (e.g. Longland Resources, Previsico, Assimila, Geospatial Insight, Bluesky, 2Excel Aviation), Global NGO's (e.g. WWF), UK national and local Government (Defra, BEIS, UKSA, Health and Safety Executive, Parliament, and Leicester City Council), the EU (European Environment Agency), international space agencies (including ESA, NASA and JAXA), other research organizations (BGS, James Hutton Institute, National Physical Laboratory, and the Centre for Ecology and Hydrology, CEH). For example, our research collaboration with Defra and agricultural businesses operating on peat soils in eastern England is being used to design and assess carbon emission mitigation measures (**Page, Kaduk**). We collaborate closely with industrial partners on developing innovative satellite-based instruments, mission concepts and services via ESA. We are also active in the SPace Research and Innovation Network for

Technology and East Midlands Centre for Excellence in Satellite Applications (10 projects with a total value of £650k).

Being at the vanguard of **Anthropocene** research has raised our national and international profile. We have made substantial contributions to the arts and humanities, opening up a wealth of historical, literary, political, anthropological, and philosophical investigations of the Anthropocene. The concept has generated at least three new journals, thousands of articles, scores of books (several authored by **Williams**, Zalasiewicz), a major film, art installations, and new institutes worldwide. It was used as a framing concept in recent IPCC and WWF reports. **Williams**, Zalasiewicz and **Zinke** sit on the Anthropocene Working Group, responsible for formally defining this new chronostratigraphic unit. At Leicester, there is a multi-disciplinary Anthropocene group which coordinates a multi-national €800k grant from Berlin's Haus der Kulturen der Welt to the AWG to define the chronostratigraphic 'golden spike', along with several public dissemination activities. We are increasingly applying our expertise in classical palaeontology (supported, *inter alia*, by a Leverhulme Trust International Network to **Williams**) and **palaeoecology to address pressing questions raised by the current global biodiversity and climate emergencies** (e.g. in ocean systems: **Zinke** with partners in Germany, Australia, France, Madagascar, Malaysia and South Africa).

The CSRE (**Jenkin, Smith, Holwell, Miles**) is actively working with industry to ensure the **security of supply of metal resources needed for future green energy technologies** and **reduce the environmental footprint** of metal extraction and processing. This includes a joint venture with Argo Natural Resources Ltd (**Jenkin**), and colleagues from chemistry, to develop new deep eutectic solvents for ore processing, replacing cyanide, reducing energy, water usage and minimizing the toxicity of waste products.

Collaborations in **Land Use Change and the Terrestrial Carbon Balance** are extensive. The UKRI Landscape Decisions Programme Co-ordination Team (**Balzter** and **Whelan** with colleagues from Geography, Mathematics, and LIAS) is working with over 50 component projects and a wide stakeholder community to improve landscape decision-making, partly to support Defra's 25-year environment plan. **Balzter** is also leading the **NCEO's ODA Programme** (£413k, NERC, **Remedios** and **Balzter**). The Leicester components of this programme are developing better satellite-based methods for forest carbon monitoring in East Africa and air quality alerts to improve human health in South-East Asia. CLCR and the University of Edinburgh (with spin-off company) collaborated in the **UKSA-funded FORESTS 2020** project that brought together the UK's leading experts on forest monitoring with overseas partners from Indonesia, Brazil, Columbia, Mexico, Ghana and Kenya. This project developed an open-access App to give near-real-time satellite-based deforestation alerts to enable timely field interventions by rangers. In addition to ICS3, we have been involved in collaborations on global peatlands; revising estimations of carbon storage, improving our knowledge of their behaviour, and better-understanding anthropogenic degradation. The 'CongoPeat' project (**Page** and **Boom**) has delivered policy impacts, such as the Brazzaville declaration of the UN Environment Programme. We are also a major partner on the UKRI-GCRF **Multi-Hazards and Systemic Risks** programme, led by Exeter with several other UK and Indonesian partners (**Page**). This is focused on interactions between development, drought and peatland fires in Indonesian Borneo and hazards for conservation in the context of the Covid-19 pandemic (**Harrison** and **Page** 2020 *PeerJ*).

Work on **Environmental Pollution** (e.g. **Whelan** and **Harrison**) focusses on the fate and effects of organic pollutants in air and water. **Harrison's** work on halogenated compounds in the atmosphere involved collaborations with UK organisations and researchers from Canada, Belgium, Norway, Switzerland, Australia and the USA. **Whelan** has worked closely with colleagues at the Norwegian Institute for Air Research, the University of Stockholm, and with

the Global Silicone Industry on the fate of Volatile Methyl Siloxanes in aquatic systems. This work (e.g. Krogseth et al., 2017 ES&T) has been cited in European Chemicals Agency reports considering restricted uses of these chemicals in Europe (e.g. ECHA 2018: Article 57d&e).

Our collaborations in the areas of **Climate Change and GHG Emissions** are extensive. For example, **Boesch** is a key member of ESA's CCI GHG Study Team with U. Bremen, SRON, BIRA/IASB, DLR, LSCE, MPI-BGC (and the Copernicus Climate Change Service), producing high-quality data sets to challenge climate models and estimate emissions. **Ghent** leads the equivalent ESA CCI LST project with a world-leading team from KIT, IPMA, U. Reading, UK Met Office, Estellus, and U. Valencia amongst others). **Remedios** has also contributed to the EU Horizon 2020 FIDUCEO project, setting up new systems to inter-calibrate satellites to climate accuracy by combining insights from metrology with the observation of the Earth's climate from space (in collaboration with U. Reading, NPL, Centre for Environmental Data Analysis and international partners in Germany and Portugal).

We have actively designed a number of **public engagement** activities. The UoL SEIS-UK team led a major outreach project to disseminate applications of seismology to school children, successfully stimulating enhanced interest in Geophysics. This involved collaboration with the UK School Seismology Project at the BGS, recording crowd-generated seismic signals of football goal celebrations ('VardyQuakes', after Leicester's top striker) during Leicester City Football Club's Premier League winning season. This generated widespread media attention from BBC World Service, Radio 1, 2 and 5; Sky Sports News, BBC One (One Show), Sky One and CNN. Subsequent work with National Youth Agency, Leicester City in the Community, the National Space Academy, and the BGS developed a curriculum-focused teaching resource, 'Geophysics in a Box' (with a low-cost Lego seismometer for hands-on workshops), that has been presented to over 200 school groups.

NCEO's EO Detective project was launched in 2015, looking at 50 years of environmental change from space (funded by UKSA and NERC). This included a suite of EO-based classroom activities for 5 to 16 year olds, accompanied by free downloadable resources. Over 4000 teachers and 140,000 children have used these resources. They have also been adopted by organisations including ESERO-UK (Tim Peake Primary Project), STEM Learning (Polar Explorer Programme), NERC and the Association of Science and Discovery Centres (Operation Earth), The Scout Association (Astronautics badge supporting materials), and the Institute for Research in Schools (MELT project).

Leadership, recognition, and esteem

High-profile advisory panels. Several colleagues hold positions of esteem on national and international organisations. These include: ESA mission advisory groups e.g. Copernicus Anthropogenic Carbon Dioxide Monitoring Missions (**Boesch**), Copernicus LST Monitoring Mission (**Ghent**), and the Far Infrared Out-going Radiation Understanding and Monitoring Mission (FORUM). **Balzter** was a member of the European Space Sciences Committee and serves on the Scientific Steering Committee on Land Use/Land Use Change and Forestry for the BEIS National Greenhouse Gas Account. **Page** is a member of the Independent Peatland Expert Working Group of the plantation company Asia Pacific Resources International Holdings Ltd., served on the Indonesia Peat Prize Scientific Advisory Board and is Chair of the Borneo Nature Foundation, the UK Peat Society, and the Scientific Advisory Board for the Leverhulme Centre for Wildfires, Environment and Society (Imperial College). **Jenkin** is Board member of Extractive Metallurgy and Mineral processing. **Holwell** is Regional European Vice President for the SGA. **England** is Ex-Officio member of NERC's Geophysical Equipment Facility Steering Committee. **Zinke** is an active member of the Past Global Changes (PAGES) 2k consortium under the Future Earth initiative to synthesize palaeoclimate data from multiple geo-archives and serves as IPCC Expert Reviewer for WG1 and the Ocean special reports.

Whelan serves on the UK Government's Expert Committee on Pesticides. **Smith** is currently a seconded fellow with the Parliamentary Office for Science and Technology (POST, is Chair of the Mineral Deposits Studies Group). **Remedios** is Principal Investigator for the Along Track Scanning Radiometer (ATSR) series of instruments, Chair of the Advanced ATSR Science Advisory Group and Chair of the Traceable Radiometry Underpinning Terrestrial- and Helio- Studies TRUTHS Mission Advisory Group. He is also a member of the UK Space Sector Council, the UKSA Earth Observation Advisory Committee and Board member for the Space Growth Partnership, providing oversight of, for example, the UK space industry report to government 'Prosperity from Space' (setting out a vision for enhanced growth in the UK space sector over the next decade).

National and international peer reviewed journals, colleges, panels and conferences: UoA7 staff serve as editors on 17 leading disciplinary and interdisciplinary academic journals (e.g. **Tansey** is Editor in Chief *International Journal of Remote Sensing*; **Espirito-Santo, Kaduk, Baltzer** for *Remote Sensing*; **Berrio** for *Frontiers in Ecology and Evolution*; **Zalasiewicz** for *The Anthropocene Review*; **Holwell** for *Economic Geology*; **Purnell** for *Palaeontology*; **Wheelan** for *Soil Research*). Several colleagues are active in peer review colleges and panels, particularly NERC (x9): UKRI/GCRF; European Space Sciences Committee (ESSC) of the European Science Foundation; Finland Academy of Sciences; French National Research Agency; Cyprus Research Promotion Foundation; the Helmholtz Society, Germany; the Irish Centre for Applied Geology; the Leverhulme Trust; the National Geographic Society; the National Environmental Isotope Facility strategy group; Global Observations of Forest Cover Fire Implementation; the US National Science Foundation, and the South African National Research Foundation. Staff have given approximately 50 invited lectures and keynote addresses at national and international organisations and regularly Chair conference sessions.

Prizes and awards. These include the Copernicus Masters Award recognizing innovative solutions to sustainability challenges based on EO data (**Balzter**); the Cuthbert Peek Award of the Royal Geographical Society for advancing geographical knowledge of human impact through EO (**Balzter**); the Theodore Sperry Award of the Society for Ecological Restoration for pioneering work on peat swamp forest biodiversity (**Page**); the Prestwich Medal of the Geological Society of London (**Zalasiewicz**); the 2015 Coke Medal of the Geological Society of London (**Davies**); the Royal Society Wolfson Research Merit Award (**Balzter** and **Zinke**).

In conclusion, UoA7 research at Leicester has witnessed a major transformation over the last 6 years. Our environment has enabled a resilient, diverse, and sustainable portfolio of support, allowing us to maintain and grow a world-class research community to address the most important, urgent and exciting challenges in Earth and Environmental Science. Our strategic vision has developed and driven our approach—as a community we are individually diverse but united in our purpose to make significant and meaningful contributions to the Research base and to economic, societal, and environmental wellbeing.