**Guidance for developing and submitting ideas for strategic research**

NERC is inviting ideas for scientific advances that address the challenges set out in our strategy *The Business of the Environment*: benefiting from natural resources; resilience to natural hazards; and managing environmental change. These ideas will be used to inform the development of new strategic research investments.

Ideas submitted by the community through this process will primarily be used to develop strategic programme areas and highlight topics, but ideas may also be used to develop investments through other funding routes.

**What is an ‘idea’?**

By an ‘idea’ NERC means a statement of a possible course of research, presented for example as a sharply focussed question, gap, challenge or opportunity, that the proposer(s) consider would contribute to the delivery of the NERC strategy goals (benefiting from natural resources; resilience to environmental hazards; managing environmental change). This invitation is to submit ideas for strategic research and NERC’s agreed definition of strategic research is as follows:

NERC’s main goals are to understand and predict how our planet works, to manage our environment responsibly as we pursue new ways of living, doing business, escaping poverty and growing economies, to broker strategic partnerships and to invest in world class skills to maintain the health of the UK environmental science community for the longer term. NERC strategic research should deliver new understanding that will, over time, contribute to addressing some of these major challenges of the 21st century: benefiting from natural resources, resilience to environmental hazards, and managing environmental change. Supporting and developing areas of world-leading scientific endeavour that are relevant to these goals is therefore strategic, including supporting such science whose specific benefits will become clear some time after the research is undertaken.

NERC is seeking different ideas for highlight topics and strategic programmes:

- Ideas for highlight topics should be sharply focused defined topic areas that can be delivered by independent projects up to the value of £4 million over a maximum of four years. Highlight topics should not require NERC to partner with other funding agencies in order to deliver the project.
- Ideas for strategic programme areas should address large scale science questions where the research is expected to be complex, logistically challenging, and/or there are significant opportunities for partnership. The programmes will require a community effort to deliver and may be up to £20 million over six years, depending on their scope.

**Submitting an idea**

Ideas can be developed by an individual or group within the research community. Ideas from those who use environmental science, such as business and policymakers, are also encouraged. It should be noted that there is no NERC funding available to support the development of ideas, but
NERC staff are available to discuss your ideas and provide advice, especially on sections where you feel you might find it difficult to provide the level of specificity we have requested. In addition, NERC staff can:

- Identify related current investments or critical masses of expertise in particular science areas through research programmes or projects, and facilitate users to connect with relevant expertise to seek input into ideas.
- Direct users to relevant events convened by other organisations, such as learned societies, which often hold discussion meetings on topics of relevance to NERC’s remit/strategy and will in some cases proactively organise the community to identify research priorities.

If you have any queries on the process or would like advice on a potential idea please contact us at idea@nerc.ac.uk in the first instance, and we will put you in touch with a NERC colleague who can help.

**Example ideas**

Two examples of ideas that had a useful level of specificity are included at Annex A. There is no perfect exemplar but these example ideas set out where scientific advances are needed to resolve issues, but importantly are not framed as proposals on how to deliver the scientific advances.

- The Southern Ocean’s role in the Earth system (submitted as a potential SPA)
- New Insights into the Space Weather Impact on the UK National Grid

**Templates**

Ideas should be submitted on the appropriate template, and include the following information:

- **Title**
- **Statement of the idea:** a short summary of the idea, around 200 words, suitable to be published on the NERC website
- **Research question(s):** a description of the scientific advance needed, its timeliness and novelty. The advances should be well-defined and specific and appropriate in scale for a highlight topic or strategic programme area.
- **Challenges:** a description of the impact the research will have, specifically how the idea and expected outcomes of research will contribute to the understanding of at least one of NERC’s challenges
- **Partnerships (for strategic programme areas only):** a note of potential collaborations and partnerships, either UK or international, that would be beneficial. Where the idea extends beyond NERC remit, this section should identify critical partners. It is not necessary to have engaged with/ obtained agreement from proposed partners before submitting an idea. NERC will do this task if the idea is taken forward and results in an approved strategic programme.
- **Capacity:** whether the UK community has the capacity and infrastructure needed to do the research, including, if applicable, how the research builds on and complements existing activities. Required new capital investments and evidence for training needs
should be specified in this section.

- **How the idea originated and has been developed:** including a note of the organisation(s) involved, and how the idea was generated, e.g. through workshops. This section should not include any individually identifiable information.

- **Type of investment needed:** identifying why a highlight topic or strategic programme investment is most appropriate for the idea.

The ideas should be submitted to idea@nerc.ac.uk using the appropriate template (highlight topic or strategic programme area) provided on the NERC website and at Annex B. The template also includes identification questions and classification questions for analysis of the ideas by NERC. Ideas can be sent to NERC at any time, although there will be regular cut-off dates for ideas to be considered by SPAG in a particular round. The cut-off dates will be published on the NERC website.

**ODA research and the ideas process**

NERC recently clarified that only small amounts of the UK’s Official Development Assistance (ODA) environmental research funding will be identified and allocated within NERC’s strategic research budget, with the majority funded from sources outside of NERC’s budget. Community members considering submitting ideas for highlight topics and strategic programme areas should consider carefully whether ODA-eligible research ideas may be better directed to the Global Challenges Research Fund (GCRF) and Newton Funds in the first instance. Further advice from NERC on this can be sought from idea@nerc.ac.uk.

**National capability research and the ideas process**

NERC’s national capability (NC) funding supports science that is vital for UK environmental science in the long term, but whose scale and complexity means it cannot be delivered in an openly competitive way. For example, capability may only exist in one place such as in NERC’s research centres or large research infrastructure (e.g. ships, aircraft and polar bases). Programmes funded through NC can provide the foundation for other NERC-funded activities and NERC welcomes the submission of ideas which build upon and maximise the value of science and infrastructure funded through NC.

**What happens to ideas?**

Once an idea is sent to NERC, the proposer relinquishes ownership of that idea and it becomes owned by NERC. The Strategic Programme Advisory Group (SPAG) will review all the ideas, drawing on specialist expertise where this is needed, and prioritise potential highlight topics and strategic programme areas. SPAG will not know the identity of those submitting ideas, but will have information on whether the idea was developed by an individual or a group.

Prioritisation will be based on the following criteria:

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<tr>
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<tr>
<td>Potential for scientific excellence</td>
<td>Research question section</td>
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<tr>
<td>Timeliness and urgency of research question</td>
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<td>Extent to which topic is already being or has recently been funded</td>
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Process for highlight topics

We intend that highlight topics will be developed from single ideas or very few closely-related ideas; for example, SPAG may choose to match up ideas where a research user has strongly outlined a problem with an idea from a research provider specifying the science advances and UK capacity. SPAG will review the ideas for highlight topics and provide NERC’s Science Board (SB) with a ranked recommendation of proposed highlight topics. SB will decide where the line is drawn to allow a degree of competition within available funds. There will be an open call for proposals across the HTs selected by SB.

Process for strategic programme areas

SPAG will review the ideas for strategic programme areas and provide SB with a number of potential areas for further discussion. SB will discuss with SPAG and decide which of the potential strategic programme areas should be developed further. SPAG and the NERC Executive will work closely together, engaging the environmental science research and user communities, to develop a full case. This will be presented to SB for further consideration, and if appropriate, to NERC Council for approval. If approved, the programme will be launched and open calls for proposals announced.

Feedback and longevity of ideas

NERC will announce regular cut-off dates and SPAG will prioritise highlight topics and potential strategic programme areas from each round. After each round NERC will provide feedback to the community; we anticipate this feedback will be high level.

For ideas submitted as potential highlight topics the feedback will inform the submitter whether (a) their idea contributed to a highlight topic (b) whether it was felt to have potential but needed further development, or (c) whether it was not considered to be appropriate for strategic research investment at this time. Individual feedback will be given on the ideas in category (b) on how the ideas could be improved for future cut-offs.

For ideas submitted as potential strategic programme areas the submitter will be informed whether (a) their idea was used to develop a proposal for a strategic programme area or (b) not prioritized as a strategic programme area at this time. Submitters of ideas in category (b) will be given individual feedback on their idea. We will also announce any refinements to the process and the next cut-off dates. Ideas will have a lifetime of a single round to ensure they remain timely.

ANNEX A: Examples ideas

This annex contains two examples of ideas that had a useful level of specificity.
There is no perfect exemplar but these ideas set out where scientific advances are needed to resolve issues, but importantly are not framed as proposals on how to deliver the scientific advances:

- The Southern Ocean’s role in the Earth system (submitted as a potential SPA)
- New Insights into the Space Weather Impact on the UK National Grid

**Example 1: The Southern Ocean’s role in the Earth system**

**Text of the idea that was submitted to NERC**

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<td>The Southern Ocean is the site where much of the interior ocean ventilates to the atmosphere, and much of the interior water masses are formed. As a result, it exerts enormous influence over the whole Earth System, with profound socio-economic consequences on the lives and livelihoods of its inhabitants.</td>
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<td>(a) It is critical to the global carbon budget, central to understanding past natural atmospheric CO₂ variations, and taking up much of the anthropogenic carbon absorbed by the ocean.</td>
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<tr>
<td>(b) It is where a large proportion of the excess heat associated with global warming is being stored.</td>
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<tr>
<td>(c) The up- and downwelling of nutrients in the Southern Ocean is a key process that drives biological productivity over much of the globe.</td>
</tr>
<tr>
<td>(d) The Southern Ocean upwelling is the major influence on the stability of the Antarctic ice sheet, with profound consequences for the rate of future global sea level rise.</td>
</tr>
<tr>
<td>(e) It is the region most sensitive to the onset of ocean acidification, with widespread impacts on biodiversity and the biological influence on climate.</td>
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However, the Southern Ocean is also the biggest data desert on the planet, especially in winter. This has severely hampered progress in understanding its role in these processes. Our current climate and earth system models disagree (with each other, and with the measurements such as they are) on almost all the important issues concerning Southern Ocean heat and carbon uptake, contribution to sea level rise, mechanisms and formation rates for deep water, and causes of past natural change. Similarly, they disagree on how the region will respond in the future under climate change.

To address these issues we propose a major, multi- and cross-disciplinary programme of observations, theory and modeling, reaching across physical, biogeochemical, paleoceanographic and cryospheric disciplines, using ships and autonomous vehicles, remote sensing and earth system models, and involving many institutions in the UK and partnerships abroad.

The programme we propose would consist of:

1) A large-scale observational programme, greatly expanding the geographical, seasonal and cross-disciplinary extent beyond planned NERC long term science projects, and having a special focus on the upper-ocean processes that are fundamental to the Southern Ocean’s role in climate. Central to this will be the extensive deployment of autonomous systems to enable crucial year-round data to be collected.
2) A major biogeochemistry programme, including measurements of micronutrients, tracers and other key variables that are required to understand the biological carbon sink, and the controls on the rates and patterns of acidification.
3) Targeted investigations of the impact of the Southern Ocean on the Antarctic ice shelves and ice sheet, using autonomous and other novel technologies, to reduce uncertainty concerning the future contribution of Antarctica to sea level rise.
4) A Palaeo-oceanography programme to generate new insight into the global and local consequences of past variation in Southern Ocean circulation, sea ice extent and biogeochemistry, in response to forcings...
that were very different from the present day.

5) A coherent and ambitious theory and modelling programme to gain insight into the key dynamical and biogeochemical controls of the Southern Ocean system, and their representation in predictive Earth System models.

6) Most importantly, strong cross-linkages between all the above programmes: a full understanding of the Southern Ocean’s role in the Earth system will involve active and intense cross-disciplinary research.

The proposed programme will benefit from NERC’s planned long term science activities and infrastructure in the region. However, it will be several times larger, in terms of the number of scientists involved, the scale of the observations to be made and the ambition to reach across all the relevant disciplines, than what can be achieved by NERC institutes alone.

**Research Question(s):**

1) What are the key mechanisms that control the strength of the Southern Ocean overturning circulation, and associated carbon and heat uptake, and their response to changing climatic forcing? How has carbon uptake and outgassing changed in the past, how will it change in the future, and what will be the climatic and ecological consequences?

2) What are the key mechanisms that control Southern Ocean heat delivery to the Antarctic ice sheet, and what are the consequences for the stability of the ice sheet and sea level rise?

3) What is the balance of the limiting factors controlling the biological carbon pump in the Southern Ocean, and how are these modulated by climate change, both past and future?

4) What is the scale, scope and consequence of past natural variation of the Southern Ocean and Antarctic ice sheet on decadal to orbital timescales? What are the natural modes of operation and thresholds, and have we already entered a non-analogue world?

Timeliness of the science: Improved predictions of climate and sea level rise require substantially improved understanding of the key processes, and the ability to include them in the relevant predictive schemes. These issues are societally urgent and require action now.

**Challenges:**

By addressing a major strategic programme consisting of a multi-disciplinary attack on the Earth-system roles of the Southern Ocean, NERC could take a global lead in making a major advance in our understanding and predictive ability of the Earth system, ‘how the planet works’. This is a central goal of NERC, as described in the NERC strategy document “The business of the environment”.

**Partnerships:**

The scale of these problems is such that the UK cannot attack them alone; instead there needs to be coordinated international action. This SPA would connect to the just-starting US SOCCOM programme, funded for 6 years with clearly defined activities that the SPA would complement, as well as the Southern Ocean programmes of other countries such as South Africa, Germany and Australia. We also have a window of opportunity to connect to the LTSM ORCHESTRA programme, and to build off its infrastructure and scientific context.

**Capacity:**

We have the capacity for this research. In particular we have:

1) a role as leading international players in Antarctic waters.

2) a massive investment in polar infrastructure, including the new polar research vessel.

3) strength and heavy investment in autonomous observations.

4) large and strong physical oceanography, climate, biogeochemistry, paleo-oceanography and modelling communities. The majority of the scientists involved are located in the HEIs.

**How the idea originated and has been developed:**

Extensive discussion over more than a year with the academic community (representatives from Universities of Liverpool, Oxford, Cambridge, Exeter, Southampton, Bristol, St Andrews, Nottingham, Reading, Imperial College, East Anglia), NERC institutes and associated laboratories (NOC, BAS, PML), the Met Office, and some SMEs involved in autonomous marine vehicles and sensors. Discussion included representatives of the physical, chemical, biological and paleo-oceanographic communities, and climate modellers. Many of those who submitted ideas individually to last year’s SPAG call are supporting this submission. In addition, discussion with the SOCCOM community in the USA (Caltech, Princeton, Scripps,
WHOI) and South African researchers at CSIR.

**Identify why this idea is a SPA:**
The research proposed addresses large-scale, strategically important science in a region which is logistically challenging, but where the UK has historic strengths. Major resource and a cross-disciplinary programme are required in order to make a step increase in our knowledge. We suggest the programme should be 5-6 years long, and will cost near £20m.

**Example 2: New Insights into the Space Weather Impact on the UK National Grid**

**Text of the idea that was submitted to NERC**

**Title: New Insights into the Space Weather Impact on the UK National Grid**

**Statement of the idea:**
Space weather links solid Earth, atmospheric, ionospheric and magnetospheric processes providing cross-disciplinary research opportunities on a natural hazard now established on the National Risk Register. In this Highlight Topic we focus on the rapid, high amplitude geomagnetic field variations, caused by space weather, that drive damaging Geomagnetically Induced Currents (GIC) through conducting networks such as power grids, pipelines and railways. Though existing UK GIC models are recognized for their geophysical detail, new insights are needed on the science underpinning these models. For example, what is the appropriate spatial and temporal characterisation of ionosphere electrical currents in respect of GIC, what can we learn from the limited verification of modelled UK geo-electromagnetic fields, and what is the best 3D model of subsurface electrical conductivity? Furthermore, industry needs GIC forecasts to prepare for impacts on electricity transmission. However GIC forecasting is a ‘hard’ geophysics problem, because of the non-linearities of the coupled Earth system, driven as it is by the solar wind. We therefore propose in this Topic to enhance our geophysical understanding of how the UK near-surface and subsurface responds to space weather. This will require more sophisticated modelling and monitoring and will ultimately lead to tools for assessing space weather impact on grounded infrastructures like the National Grid, together with industry and other partners.

**Research Question(s): Advances needed, their novelty and timeliness**
NERC GIC models have gradually developed in association with the UK power industry over more than 10 years. But it is time for a step change in modelling capability and accuracy, as the current generation of models have significant scientific limitations, revealed by recent validation against measurements, and limits in operational settings, because industry’s needs have evolved. By concentrating on the following research questions NERC can reach a new level of scientific knowledge in this field and create a new generation of world-leading research models with operational value, in a time frame better suited to industry and other stakeholder needs.

**RQ1 - Ionospheric and magnetospheric processes**

- How do ionospheric electrical currents respond to space weather forcing? How does the morphology and dynamics of current systems change under higher levels of forcing? What are the extremes in ionospheric currents at mid and high latitudes?
- What is the relative significance of, and interaction between, the ionospheric-magnetospheric current systems and their dynamics in terms of ground magnetic variations, under varying space weather forcing? What spatial and temporal scales in these magnetic variations are most significant in terms of GIC?
- What are the limits to forecasting in the ionospheric-magnetospheric system and what are the implications, e.g. in terms of quantifiable uncertainties, in forecasts of GIC in power grids?
- Are there meso- (i.e. UK continental shelf) scale geomagnetic processes that are not resolved by the current UK magnetometer network? Is any such structure related to, or predictable from larger scale or mean fields? How does any meso-scale structure influence generation of GIC?

**RQ2 - Solid Earth processes and structures**

- How does the surface electric (telluric) field behave at major shallow and 3D conductivity contrasts during magnetic storms, particularly at the coast where electricity generation is concentrated?
- What is the relative importance of deep (~hundreds of km) and shallow (~few to tens of km) conductivity and of magnetic variations, on surface electric fields driven by space weather?
- How do decadal, or longer, changes in the Earth’s magnetic field generated in the core influence the structure and dynamics of ionospheric-magnetospheric currents? What are the potential impacts in terms of GIC on grounded infrastructure?

**Challenges:**

**Resilience to Environmental Hazards**

The challenge in this Highlight Topic is to better understand our changing resilience to the natural hazard of space weather within a critical national infrastructure, the National Grid. Addressing the specific Challenges 1 & 2 below will therefore have impact through the development of models and tools that can be used to better assess the exposure of the Grid to this hazard.

**Challenge 1 - Ionospheric and magnetospheric processes**

Coupled ionospheric-magnetospheric current systems generate ground-level magnetic field changes that create GIC through an induced electric field in the Earth. The dynamics of these currents have a complex dependence on energy and plasma extracted from the solar wind. Existing models of these currents are largely derived from satellite measurements in orbits beyond a few Earth radii. However the electrical currents in the magnetosphere and ionosphere that drive significant GIC in the UK are much closer to the Earth’s surface and are poorly represented in existing GIC models. We need progress on the novel research questions (RQ1 above) to improve models of ionospheric-magnetospheric current systems close to the Earth, ultimately leading to a predictive GIC capability driven by solar wind measurements.

**Challenge 2 - Solid Earth processes and structure**

The surface electric field induced in the Earth that drives GIC in the grid is sensitive to Earth conductivity and geological structures. However, present day conductivity models have limited parameterisation of 3D varying structure and often lack shelf-sea, deep-sea and sediment conductivities, particularly important for the UK. Electric fields are also not widely monitored, so models lack country-wide validation. Nor do we understand how long term changes in the Earth’s core magnetic field affects the ionosphere-magnetosphere ‘climate’ and the significance of this for GIC. To improve our models of surface electric fields and of solid Earth control on the ionosphere-magnetosphere environment, we need to address the key questions identified at RQ2 above.

**Capacity:**

This Highlight Topic should encourage cross-disciplinary research into coupled geoelectromagnetic processes from the deep subsurface to near-Earth space, as it builds on existing academic and industry partnerships. For example, BGS operates the NERC magnetic observatory network and has more than 15 years’ experience in modelling GIC in the UK grid in association with National Grid, Scottish Power, EDF and ESA. Expertise in ionospheric and magnetospheric activity, driven by the solar wind, exists at BAS, RAL and the University of Lancaster. Lancaster runs the SAMNET magnetometer array and operates a popular outreach project, ‘Aurora Watch’. Edinburgh, Liverpool and Leeds Universities are strong sources of expertise in solid Earth Geomagnetism. Met Office has been the UK lead space weather forecaster since 2014.

**How the idea originated and has been developed:**

This idea originated through workshops (2012-) on space weather and GIC, involving Leeds, Edinburgh, and Lancaster universities and BGS, BAS, Met Office and RAL Space. The idea has further benefited through recent international partnerships and workshops, with NOAA & NASA, supported by the Foreign Office and Cabinet Office Civil Contingencies Secretariat, and workshops supported by the EU Joint Research Centre, European Space Agency and the insurance industry (‘Geneva Association’). This Topic should facilitate a partnership between NERC, Met Office, National Grid, electricity utilities and Government, with economic and societal impact and recognition at international level.

**Identify why this idea is a HT:**

This Topic is highly focused on better monitoring, specification and forecasting of a particular aspect of space weather, GIC, and its impact on the National Grid. However there is a wider scientific gain: better understanding of geophysical processes in the near-surface and subsurface geoelectromagnetic environment across the UK and the response of these processes to forcing by solar activity. Additionally, any potential capital investment (magnetometers, telluric probes) is relatively inexpensive and scientific expertise in the UK is concentrated in a few institutions.
ANNEX B: HIGHLIGHT TOPIC AND STRATEGIC PROGRAMME TEMPLATES

Idea template
Highlight topic

Your idea should be written in language that is clear to a broad section of the NERC community and be up to 2 sides of A4 (not including the classification questions) using size 11 font and margins no less than 2cm.

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<td><em>highlight topics are sharply focused, defined topic areas that can be delivered by independent projects up to the value of £4m over a maximum of 4 years.</em></td>
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Submitter and classification questions (responses in this section will be used by the office to analyse the ideas. SPAG will not see submitted details, but will be informed of the nature of the ideas generation)

<table>
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| Which part of the environmental science community do you consider the idea to be mainly from? |
| Research base |
| Public sector |
| Industry/commercial |
| Third sector |
| Other (please specify) |

| Indicate the percentage relevance to one or more of the NERC challenges (multiples of 5%, totalling 100%) |
| Resilience to environmental hazards |
| Benefitting from natural resources |
| Managing environmental change |

| Indicate percentage relevance to the scientific areas in which your idea falls (multiples of 5%, totalling 100%) |
| Atmospheric |
| Earth |
| Freshwater |
| Marine |
| Terrestrial |

| Indicate the percentage relevance to any of the secondary classifications appropriate to your idea (multiples of 5%) |
| Earth observation |
| Polar |
| Interdisciplinary (beyond NERC remit) |

For office use only:

Date: ID:
Idea template

**Strategic programme area**

Your idea should be written in language that is clear to a broad section of the NERC community and be up to 2 sides of A4 (not including the classification questions) using size 11 font and margins no less than 2cm.

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<th>Indicate the percentage relevance to any of the secondary classifications appropriate to your idea (multiples of 5%)</th>
<th>Earth observation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Polar</td>
<td>Interdisciplinary (beyond NERC remit)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>For office use only:</th>
<th></th>
</tr>
</thead>
</table>

| Date: | ID: |