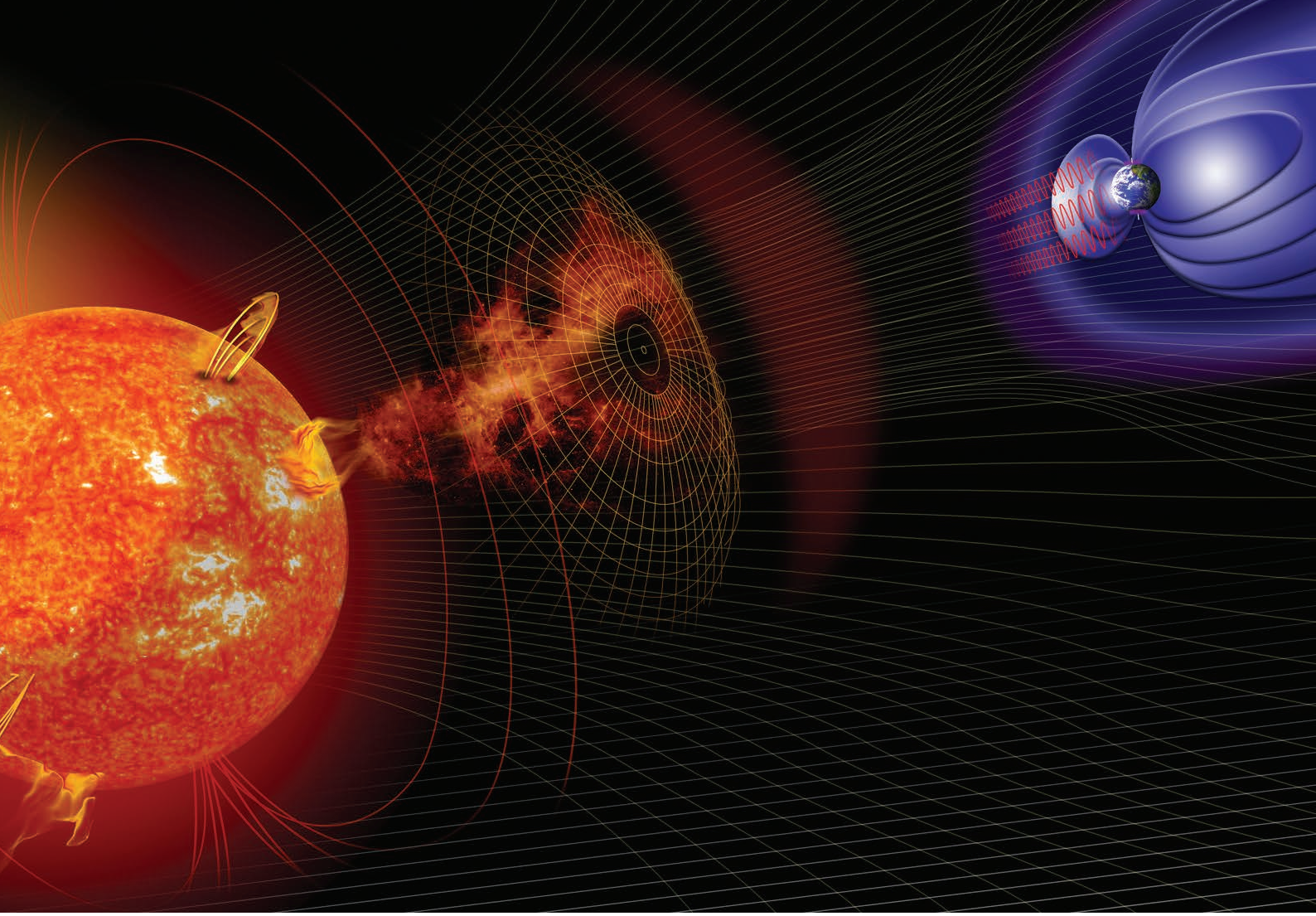

SPACE WEATHER

Public Dialogue

FINAL REPORT

11 February 2015

This report has been prepared by 3KQ and Collingwood Environmental Planning on behalf of the space weather public dialogue.

The dialogue was jointly funded by Sciencewise[1] and the Science and Technology Facilities Council (STFC). Further resourcing was provided by STFC's RAL Space, Natural Environment Research Council (NERC), National Grid and Lloyd's of London.

Cover image: artist illustration of events on the sun changing the conditions in Near-Earth space. Image credit: NASA.

1. Sciencewise is funded by the Department for Business, Innovation and Skills (BIS). Sciencewise aims to improve policy making involving science and technology across Government by increasing the effectiveness with which public dialogue is used, and encouraging its wider use where appropriate to ensure public views are considered as part of the evidence base. www.sciencewise-erc.org.uk

CALL TO ACTION

Response to the findings of the space weather public dialogue

In response to the dialogue findings, STFC led the development of a set of recommendations to facilitate action from government and members of the space weather community. This was undertaken with advice and encouragement from members of the dialogue Oversight Group.

1. EMPOWERMENT OF THE PUBLIC THROUGH KNOWLEDGE

The dialogue has shown that it is straightforward to communicate space weather risks to the public, that this is much appreciated by the public and will be a valuable contribution to society's resilience against space weather. When people have awareness of space weather (indeed of any natural hazard), they are empowered to deal with the adverse impacts. They are then aware of the likely scale of the impacts, and of what they can do to help themselves and their community. They will also become aware of wider efforts to mitigate those impacts. This all acts to reassure people and to counter media scaremongering about natural hazards.

Recommendation 1. *That Government should encourage work to raise public awareness of space weather, of the need for resilience against its adverse impacts, and of how this fits into wider resilience against a range of risks. We recommend that this work is linked with other activities, across UK and devolved governments, to promote resilience against space weather and other natural hazards. It should seek to engage all relevant departments, their agencies and non-departmental bodies (in particular the Research Councils), and should promote good practice through engagement with space weather outreach experts in Government, academia and industry. It should develop and implement an awareness-raising plan, taking note of the many issues discussed in the dialogue report, and of potential sources of financial support for outreach activities. At a minimum, this plan should include:*

- *development of a centrally-produced resource pack that could be used for local awareness raising - material that could be customised for specific websites, publications, training and exercising. This pack should be made once for the UK for best use of scare resources;*
- *development of guidance on drip-feeding space weather information to the public, e.g. through weather forecasts and other media opportunities;*
- *development of lesson packs that will facilitate the presentation of space weather in schools, and of the generic need for resilience - and also to open up the possibility to include these topics in the National Curriculum.*

2. BETTER PUBLIC VISIBILITY OF OFFICIAL ACTIVITIES

Most workshop participants were unaware of how resilience is being developed at a local level, in particular unaware of the Local Resilience Forums (LRFs) that now exist to coordinate official resilience actions at this level. However, they were pleased to learn of this and were keen to see greater public visibility of the work of LRFs and how they can complement personal and community resilience (i.e. neighbours working together). This greater visibility would be valuable both in providing reassurance to the public, and in encouraging them to contribute to resilience through personal and community action. The workshops showed clearly that members of the public are keen to take on such responsibilities when the information in recommendation 1 is available and understood.

Recommendation 2. *That all levels of government should work together to explore ways to increase public awareness of the work done by Local Resilience Forums (LRFs): namely to foster resilience, to provide a wealth of relevant*

information to the public, and as the front-line to deal with problems when they occur. One possible example emerging from the dialogue is to hold open meetings to build up links between LRFs and the communities that they serve.

3. ENCOURAGE INDUSTRY PREPAREDNESS

The vital role of industry in operating systems vulnerable to space weather was widely discussed in the workshops. Participants recognised that industry is a key player, alongside Government, in ensuring that we have overall systems resilience against space weather and thus industry should be encouraged to play its part in the provision of that resilience. This should include financial provision by industry for resilience; the costs of resilience should not fall solely on the public purse.

Recommendation 3. *That Government should continue to work closely with industries operating systems at risk from space weather to ensure and demonstrate that the UK has overall systems resilience to space weather. These partnerships should reassure the public by being open about the risk from space weather and, as far as practicable, about the measures taken to reduce that risk.*

4. FURTHER EXPLORATION OF PUBLIC ATTITUDES TO SPACE WEATHER RISKS

The present dialogue has shown the public response to the adverse impacts of space weather is focused on the threat of power cuts – and that there is less interest in impacts on other systems such as civil aviation and Global Navigation Satellite System (GNSS). This may simply indicate that the workshop participants, indeed perhaps most of the general public, still have only limited direct dependence on civil aviation and GNSS, whereas every one of us has a high direct dependence on electrical power. However, expert opinion has clearly identified significant risks arising from the wider dependence of society on civil aviation and GNSS. Thus it would be worthwhile exploring public attitudes to specific elements of these risks, perhaps by setting each element in a wider context, e.g. the aviation radiation hazard could be set in context of similar radiation hazards such as cave/underground exploration, space tourism, and human space exploration.

Recommendation 4. *That the members of the space weather expert community investigate options to explore public attitudes to specialist space weather risks. This should include discussions with relevant government bodies (UK, devolved and local) to identify areas where there are potential policy benefits from such benefits, as well as consideration of how to identify members of the public affected by specialist risks.*

EXECUTIVE SUMMARY

Background

Severe space weather is one of the highest priority natural hazards in the UK National Risk Register[2] and has the potential to disrupt many technologies critical to the functioning of modern society.

Extreme space weather events are characteristically low probability, but with the potential for a high level of impact. Our understanding of the science of space weather is currently limited, and we cannot be certain quite how severe the impacts of such an event would be.

Space weather is now firmly on the political and commercial agenda, both in the UK and on a global scale. A better understanding of how members of the public understand space weather and perceive related risks and mitigation, as well as how to communicate the nature of these risks, is therefore timely.

Purpose and objectives

The overall **purpose** of the space weather public dialogue was to inform the policy of government departments, government agencies and companies in respect of space weather and the consequences on people and infrastructure.

In order to achieve this, the project was designed to gauge public understanding of: space weather; its impacts and scenarios for resilience (both civil society and individuals); and the roles and responsibilities of the Government, companies, communities and individuals in responding to space weather impacts.

Specific **objectives** were:

1. To engage members of the public and other stakeholders in developing this work, including enabling members of the public to ask questions and develop conversations with space weather stakeholders.
2. To develop and gauge public understanding of space weather, its impacts and the resilience of civil society.
3. To consider how to improve public and stakeholder awareness of space weather and its associated impacts.
4. To determine how far members of the public think the Government and companies should go to mitigate space weather impacts.
5. To inform policy, spending, responsibilities and the priorities for action to mitigate space weather impacts.

Funders

The dialogue was jointly funded by Sciencewise[3] and the Science and Technology Facilities Council (STFC). Further resourcing was provided by STFC's RAL Space (based at the Rutherford Appleton Laboratory), Natural Environment Research Council (NERC), National Grid, and Lloyd's of London.

2. The National Risk Register provides a government assessment of the likelihood and potential impact of civil emergency risks.
3. Sciencewise is funded by the Department for Business, Innovation and Skills (BIS). Sciencewise aims to improve policy making involving science and technology across Government by increasing the effectiveness with which public dialogue is used, and encouraging its wider use where appropriate to ensure public views are considered as part of the evidence base. www.sciencewise-erc.org.uk

Process

The process centred on a set of public dialogue workshops held in three locations around the UK. There were two events held with the same group of approximately 20 people in each location. This was followed by a third workshop comprising a selection of participants from each location.

Specialists with experience in space weather science, communication, resilience, forecasting, industry and policy were present to engage in discussion and provide further information.

Alongside the workshops, a self-selecting online survey was undertaken, to collect views from a wider group of interested parties, as well as a 1,010 person representative online survey to gauge a baseline of views among the general public.

Key messages

Communicating the basics

Participants wanted clarity about what space weather is, how it might affect them and what remediation is already in place. There is a need for simple and consistent answers from government departments, agencies and other relevant organisations to the following questions:

- *What is space weather?*
- *How long could a severe space weather event last, what would the likely impacts be as a result and what can we do about it?* This could include, for example, a range of scenarios with suggestions for preparedness and actions in the event of an incident, including who to contact for help. Participants indicated their initial priorities would include contacting relatives or neighbours (particularly more vulnerable people), trying to find out more information about what is going on, and ensuring they had sufficient water and food.
- *How vulnerable is the UK?* Participants suggested that communicating uncertainty is fine as long as there is clarity over roles, responsibilities, current mitigation plans and contingency plans – i.e. who would do what.

There was some debate over the use of the phrase 'space weather' given the specific connection to the Sun's activity, though it was recognised that space weather is the commonly used phrase internationally.

Level of information

Participants said that they learned a lot throughout the process – for example that much of the information was no longer "beyond their comprehension". They wanted honest answers with respect to the consequences of a severe space weather event, but said that this should be in context – with an awareness of the ability of the media to inflate stories.

Mechanisms for wider awareness-raising

Participants came to the conclusion that wider awareness-raising activities among the general public are a good idea because they are relatively cheap and help to encourage increased personal resilience. They suggested there should be more communication about space weather, but that this had to be based on sound data.

Specifically, participants talked about drip feeding information. They said there should be a consistent low-level feed of information relating to space weather into the public domain, in order to familiarise people with the terminology and concept of space weather and reduce the chance of panic should a severe event occur. This should be non-threatening and interesting – for example focusing on already-familiar terminology such as 'northern lights' and linking it to more complex space weather language and science.

Specific suggestions to take forward were as follows:

- *Weather forecast*. There could be an occasional mention on national weather forecasts, possibly linking to further more detailed information. This could be similar to the pollen count, for example linking sighting of the northern lights with possible disruption to infrastructure.
- *Education*. There is an opportunity to work space weather or more general resilience content (e.g. responding to emergencies) into schools. Research Councils and communicators could work with schools to develop realistic scenarios and practical activities across a range of subjects such as science (magnetism, electricity), maths (data handling), home economics (cookery with basic supplies).
- *Broadcast media*. Besides potential mention on the weather forecast, suggestions included working with programme makers to develop innovative content relating to space weather or general resilience.
- *Communication resources*. Participants liked visual, interactive materials with consistent messaging. This raises the possibility of a library of resources relating to space weather or more general resilience.

Community resilience

Participants expressed a range of views about their own ability or that of their communities to cope in the event of a severe space weather or similar event. Some felt modern communities tended to be less resilient than in previous decades or that the UK as a whole is generally not used to extremes, while others felt their (rural) community is relatively well equipped.

Participants recognised the need to increase personal resilience in general, but stressed that personal action needed to come hand in hand with action from local and national government and emergency responders in terms of preparation, guidance and mitigation – increased resilience was seen as a shared responsibility and participants felt this should be communicated.

Participants made the distinction between community and local government, but did not know of the existence of local resilience forums (LRFs). Increasing the visibility of LRFs and their connections with local communities was seen as a good thing – to help members of the public understand what happens in an emergency situation and how they can prepare. More generally, improving connectedness and information provision at a local level was viewed positively, particularly with respect to helping vulnerable people.

For many participants, conversations increasingly centred on general resilience rather than being specific to space weather – for example the suggestion that measures should be taken to improve general resilience around events with common consequences.

Participants stressed the role of local and central government in informing people of events and relevant actions early, to help reduce both the level of systemic impact and the level of worry or panic among individuals and communities.

Systems resilience and the role of industry and governments

Participants recognised that better systems and technological resilience could have wide ranging benefits for individuals and society, but were concerned that the bill shouldn't necessarily always come out of the public purse. They suggested mitigation actions around aviation and power networks, for example, should be funded at by the relevant private companies, or in collaboration between the public and private sectors. Participants indicated that they liked measures with a systemic or innovative approach to resilience – for example developing more sustainable infrastructure with tools such as local solar generators and solar roof tiles.

There was a strong message that companies and governments have a responsibility to assess space weather risk, put in place contingency plans and communicate these. The idea of collaboration was discussed, with participants commenting that sharing information between agencies as far as possible was a good thing. Participants also stressed the need for local and central government to inform people of space weather events as early as possible, to help minimise the level of systemic impact and the degree of worry or panic among individuals and communities.

Forecasts, modelling and data

Participants recognised the value of forecasts and modelling as a tool to raise general awareness (for example getting people used to the idea of warnings and following up with further information about what actually happened), as well as a mechanism to assist in preparation and response to periods of adverse space weather. They expressed

support for funding further monitoring and modelling systems, adding that sound data is an essential basis for reliable communication. This included support for a new monitoring satellite, with the caveat that costs should be shared – for example internationally, or between public and private sector. Participants also thought citizen science projects were a good way to engage members of the public.

Overarching messages

Participants were clear they expected their views to be taken into account in future plans and actions. They concluded that investment in research and forecasting, the resilience of technology and systems (such as power and communications systems), and increased awareness and understanding are all important.

Turning outputs into actions

On 15th October 2014, members of the Oversight Group and other key stakeholders came together for a stakeholder summit, along with five members of the public who had taken part in all three stages of the public dialogue workshops.

Attendees discussed four key questions in relation to the dialogue findings:

- What level of public awareness is needed?
- What is the appropriate level of preparedness?
- What new knowledge is needed?
- What are you planning to do as a result of the dialogue?

Responses to the first three questions tended to fall into three categories of action, listed below.

- Things to bear in mind to frame any future activities – for example:
  - the tolerance of members of the public will be affected by their understanding of the issue
  - as much notice of space weather events as possible would be a good thing
  - there is great scope for improving modelling and measurements.
- Things that stakeholders should consider doing – for example:
  - raising awareness through multiple media channels to reach different audiences
  - developing messaging around general resilience in a 'drip feed' manner
  - developing more in-depth scenarios about what different types of space weather events might look like.
- Things that need further discussion or research – for example:
  - including space weather in the general weather forecast
  - defining what is meant by an emergency 'kit'
  - exploring how to put together a business case to better understand the true cost of a severe space weather event.

In response to the fourth question, attendees noted specific actions or commitments they would take away as a result of the dialogue. Some of these actions were personal – for example improving personal resilience. Others were organisational – for example enhancing space weather information on websites, discussing knowledge sharing between Local Resilience Forums, and raising awareness of the dialogue among colleagues or other stakeholders.

This report will be published via a launch event in early 2015 and disseminated to a range of interested parties, including members of the public who took part in the dialogue workshops. All dialogue materials and website content will be handed over to STFC. STFC will make selected materials available for re-use in space weather communications activities.

In response to the dialogue findings, STFC led the development of a set of recommendations to facilitate action from government and members of the space weather community – see Call to Action at the beginning of this report.

Contents

1. THIS REPORT

This report summarises outputs from the space weather public dialogue, highlighting key messages from participants and responses from stakeholders. It is qualitative in nature, and should be read as such. The report lays out the range of comments and views expressed by participants. It does not attribute weight to specific views.

This report is aimed at organisations and individuals focused on different aspects of space weather, including: strategy, research, observation, international coordination, risk, emergency planning and resilience, and communication. Any UK-specific terms are explained with footnotes.

The key messages in this report from workshop participants and the project team are aimed at these stakeholders with a view to helping shape future actions around space weather resourcing, priorities and communication.

Sections in this report are as follows:

- **Section 2** focuses on **PROCESS**. It provides an overview of the dialogue project, including background, process, objectives, and roles and responsibilities.
- **Section 3** focuses on **CONTENT**. It describes the findings of the project, linked to project objectives.
- **Section 4** focuses on **WHAT NEXT**, including summarising outputs from the stakeholder summit held in October 2014.

2. THE DIALOGUE

2.1 Background

Severe space weather is one of the highest priority natural hazards in the UK National Risk Register[4] and has the potential to disrupt many technologies critical to the functioning of modern society.

Extreme space weather events are characteristically low probability, but with the potential for a high level of impact. Our understanding of the science of space weather is currently limited, and we cannot be certain quite how severe the impacts of such an event would be.

Space weather is now firmly on the political and commercial agenda, both in the UK and on a global scale. A better understanding of how members of the public understand space weather and perceive related risks and mitigation, as well as how to communicate the nature of these risks, would be both useful and timely. Outcomes of the public dialogue are expected to feed into the policies and strategies of numerous organisations. Learning more about how the public perceives, reacts to and best understands space weather and its associated risks, as well as the potential impacts and responses or mitigation, will be key to informing effective policy and scenario planning on this issue.

See Appendix 1 for a more detailed account of the project background.

2.2 Purpose and objectives

The overall **purpose** of the space weather public dialogue was to inform the policy of government departments, government agencies and companies in respect of space weather and the consequences on people and infrastructure.

In order to achieve this, the project was designed to gauge public understanding of: space weather; its impacts and scenarios for resilience (both civil society and individuals); and the roles and responsibilities of the Government, companies, communities and individuals in responding to space weather impacts.

Specific **objectives** were:

1. To engage members of the public and other stakeholders in developing this work, including enabling members of the public to ask questions and develop conversations with space weather stakeholders.
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3. To consider how to improve public and stakeholder awareness of space weather and its associated impacts.
4. To determine how far members of the public think the Government and companies should go to mitigate space weather impacts.
5. To inform policy, spending, responsibilities and the priorities for action to mitigate space weather impacts.

4. The National Risk Register provides a government assessment of the likelihood and potential impact of civil emergency risks.

2.3 Destinations for outputs and outcomes

The dialogue outputs are relevant to a wide range of organisations focused on different aspects of space weather, including: strategy, research, observation, international coordination, risk, emergency planning and resilience, and communication. For example, see Appendix 2 for a list of Oversight Group members and other contributors. Findings were communicated with relevant organisations at a stakeholder summit in October 2014, and dissemination of this final report will occur in early 2015.

2.4 Funders

Sciencewise. The Department for Business, Innovation and Skills (BIS) has a Science and Society Team that runs an initiative to improve policy making around science and technology via the structured involvement of citizens – the Sciencewise programme. This provides advice and support, and also co-funding, to Government departments and agencies to develop and commission public dialogue activities and, importantly, their evaluation.

Sciencewise undertakes research, publications, seminars, one-to-one support, and advice to policy-makers. Sciencewise has co-funded and evaluated public dialogue projects on issues as diverse as animal research, nanotechnology, and wellbeing.

Science and Technology Facilities Council (STFC). STFC is one of seven publically funded research councils in the UK, supporting an academic community of around 1,700, and with a focus on particle physics, nuclear physics and astronomy (including space science). RAL Space at the Rutherford Appleton Laboratory (RAL) work alongside the UK Space Agency (UKSA) who co-ordinate UK civil space activities. They have a heritage of over 50 years and have had involvement in putting over 200 instruments in space. They have around 200 staff who are dedicated to supporting the programmes of the Council and those of the other research councils; as well as undertaking a large number of contracts for agencies, industry and other commercial customers.

Other organisations providing resources to the dialogue project included **Natural Environment Research Council (NERC), National Grid and Lloyd's of London.**

2.5 Roles and responsibilities

STFC / project lead. STFC, and more specifically the STFC project lead for the dialogue – Sarah Smart – acted as the main point of contact for the project team and Oversight Group (see below). There was regular communication between the project team and STFC, to ensure STFC was up to date with progress, seek input on specific processes and documents, share any concerns or queries, and ensure an ongoing level of shared understanding and expectation.

Project team. The core project team consisted of individuals from 3KQ and Collingwood Environmental Planning, who partnered to deliver the project: Jane Dalton (project manager), Carl Reynolds (lead facilitator), Paula Orr (content lead), and Helen Fisher (materials and reporting lead). The team and their colleagues were responsible for designing and delivering the project, including the knowledge review, all dialogue strands, analysis and reporting. The team worked with Pure Communication on design, branding and web presence, and with Ipsos MORI on workshop recruitment and the representative online survey.

Sciencewise. The Sciencewise Dialogue and Engagement Specialist (DES) for this project – Alison Crowther – provided ongoing support, advice and feedback as the process developed, playing a central role in ensuring the project delivered on its objectives and was carried out in line with the Sciencewise Guiding Principles[5] for public dialogue. The relationship

5. http://www.sciencewise-erc.org.uk/cms/assets/Uploads/Publications/Sciencewise-Guiding-PrinciplesEF12-Nov-13.pdf

between the project team, STFC and Sciencewise was one of partnership, sharing ideas and working through potential problems to deliver the best possible process.

Oversight Group. The Oversight Group (OG) acted as a constant guide and sounding board for the project. They provided input on design and materials, attended workshops as specialists and fed back their views and reflections as a result. The idea for a dialogue came out of workshop at STFC on public engagement and it was agreed that of all the issues considered, space weather was the one most appropriate for two way dialogue with the public. An Oversight Group was created, reflecting key decision-makers, actors and specialists in the subject. They came together to write a business case for funding to Sciencewise and scope out the nature of the project needed. With the help of Sciencewise they set a budget and an outline plan and let the contract for dialogue. Once the funding and delivery organisations were in place, two OG meetings were held early in the process: one at the beginning to clarify scope, roles and responsibilities, and one to discuss draft materials and the knowledge review. Following this, all communication with the OG was undertaken electronically (for example commenting on draft materials), by phone or in person at dialogue workshops. The stakeholder summit in October 2014 took the form of an extended OG meeting, to discuss and respond to the findings of the dialogue. See Appendix 2 for the membership of the Oversight Group.

Workshop attendees – specialists and observers. Most OG members attended at least one dialogue workshop to provide input in the form of presentations or responding to questions, and to engage in discussions with members of the public. They were joined by a wider group of specialists (see Appendix 2) with specific interests or roles relating to space weather or the wider field of resilience. Some representatives of specific organisations attended as observers, playing a listening role rather than taking part in conversations – these were limited to no more than three per workshop.

Specialists and observers were briefed on their role and remit at the start of each workshop. This helped to ensure their input was balanced and reflective as far as possible, rather than steering participants towards a particular point of view.

Members of the public. Members of the public were at the heart of this process, and were involved in three ways: dialogue workshops, a self-selecting online survey, and a representative online survey (i-omnibus). Public dialogue is not just about extracting information – it should be two-way, and of value to all parties involved. One of the keys to achieving this is the development of positive and relaxed relationships with all participants, in order to put them at ease, engender trust and explore *why* they think or feel what they do, rather than just *what* they think or feel. This is partly down to the working style and skill of the facilitation team, but also the workshop design – including the activities, venues, preparation and follow up communications to each event.

All participants were asked for permission to be contacted again by STFC, Sciencewise and the evaluators, with the view to three potential follow-up activities:

- STFC, Sciencewise, or the evaluators may wish to contact participants later to reflect back on the process or ask specific questions about the outputs.
- Participants may value a degree of ongoing contact in order to keep in touch with space weather research and activity.
- There is the possibility of reconvening the more highly engaged members of the public as an ongoing sounding board in the future.

Evaluators. The evaluators for this project, Icaro, were appointed to provide an independent, external view on the extent to which the project has delivered against its objectives and to extract learning for future dialogue projects.

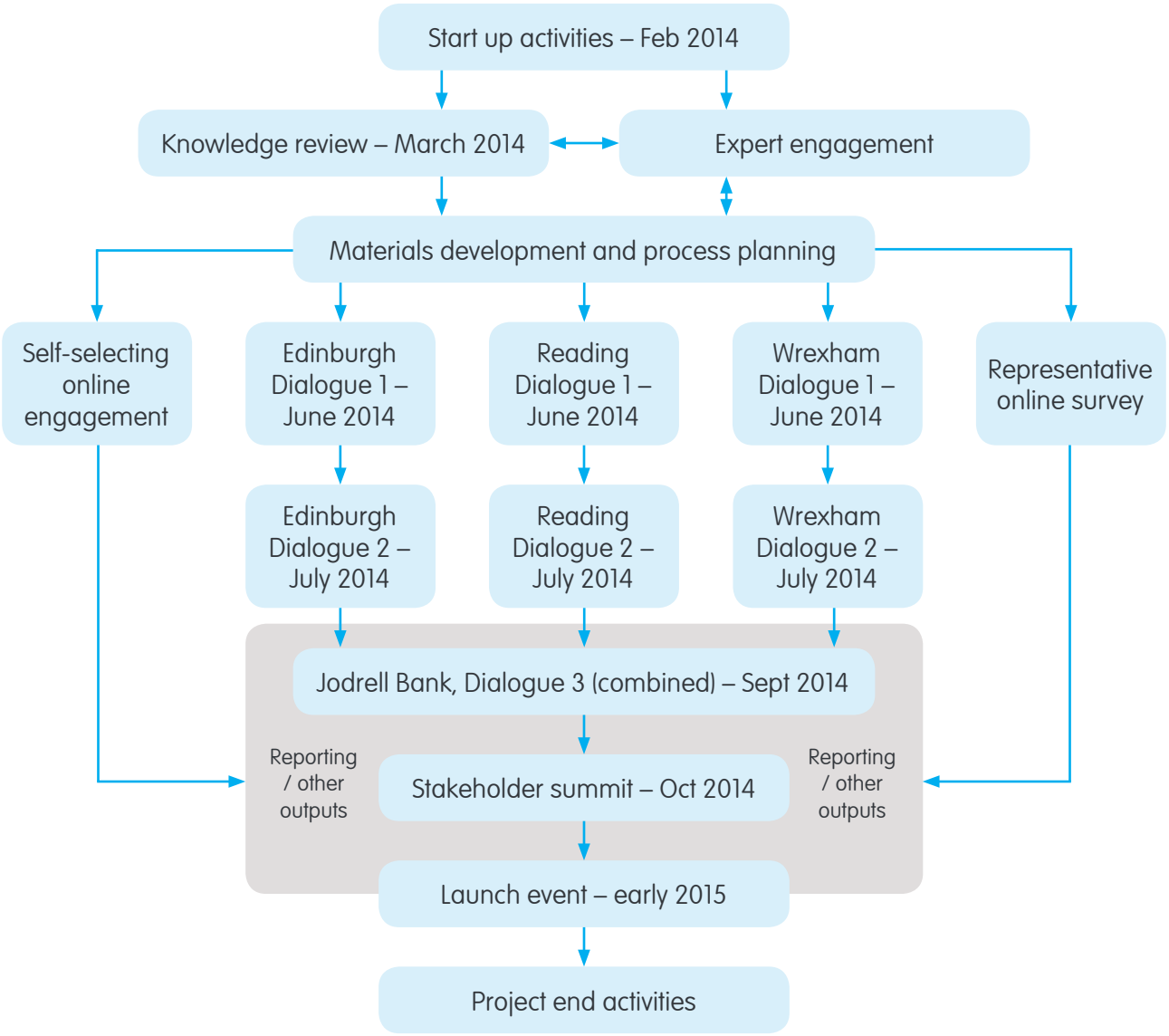
2.6 Process

The process was centred around three sets of public dialogue workshops, to reflect three different perspectives that would need to be considered in the event of an extreme space weather event: rural (Wrexham workshops), urban (Edinburgh workshops) and a national perspective (Reading workshops[6]). There were two events with the same group of approximately 20 people in each area, followed by a third workshop comprising a selection of participants from each location.

Specialists with experience in space weather science, communication, resilience, forecasting, industry and policy were present at workshops to engage in discussion and provide further information.

Alongside the workshops, a self-selecting online survey was undertaken, to collect views from a wider group of interested parties, as well as a 1,010 person representative online survey to gauge a baseline of views among the general public. Figure 1 below outlines the main process elements. Appendices 4–7 of this report provide detail on the process and structure of the overall project.

Figure 1 Process summary.



6. Reading was chosen as a diverse location more broadly in line with national demographics than the other two locations, and with less focus on purely rural or urban perspectives.

3. FINDINGS

The first stage of the dialogue process was a knowledge review, designed to assess and summarise existing background information on the likelihood and potential impacts of extreme space weather events and the ways in which these risks are currently managed, to inform the scope and design of the public dialogue. The box below summarises key points arising from the review – see Appendix 3 for an abridged version of the full review.

The remainder of this section summarises dialogue findings in relation to each of the five dialogue objectives.

Knowledge review

The review highlighted a number of issues that it would be relevant to explore in the public dialogue:

Understanding public attitudes, preferences and values in relation to the management of space weather risk, for example:

- As the emergency responder of last resort, should the Government be playing a more active role in protecting against space weather risks, for example through increasing funding for research in this area or through stronger enforcement of mitigation measures in both the public and private sectors?
- Currently there is not the knowledge or capacity to forecast space weather events as far in advance as weather on earth. What priority should be given to space weather research versus increasing research into other risks such as flooding? To what extent should the Government be promoting cooperation and information-sharing between public and private institutions in areas of activity that could be impacted by space weather events?
- How should scientists work with industry and public bodies (such as the Ministry of Defence) to map the potential 'ripple effects' of space weather events? How important is it to recognise concerns about commercial or security sensitivities in these sectors?

Exploring public views on topics on which specialists or stakeholders take different positions:

- To what extent could different parts of the UK be differentially impacted by space weather events? If there are disproportionate risks for some communities, should specific efforts be made to mitigate those risks?
- Is it important to look for evidence of very big space weather events that occurred many thousands of years ago in order to model all the possible impacts of space weather or is it good enough to use the Carrington event as the 'worst case scenario'?

Issues for communicating space weather risks to wider publics:

- It is possible to identify risk or 'fright' factors which affect the way that members of the public perceive different risks?
- Does the language currently used by specialists to describe likelihood of space weather events and the scale and severity of potential impacts on earth, make it harder for lay people to understand the risks?

Questions might include:

- **Space weather forecasting:** how interested are people in the science of space weather forecasting? What do members of the public see as the value to society of improving the capacity to predict when space weather events will occur?

- What **appetite** is there in the public as a whole **for forecasts of space weather events**? Is it important that regular information about the probability of space weather events should be communicated in a way that is accessible to the general public? What would members of the public want to know in order to understand the likelihood of a severe space weather event? What do people understand by the Carrington event having a 1 in 100 year return period?
- **Space weather impacts and exposure:** what space weather impacts are people most concerned about / can see having the greatest influence on their daily lives? How do people engage with the notion of the ripple / cascade effect from space weather? To what degree do people appreciate / understand the interrelated nature of space weather impacts?
- **Space weather vulnerability:** how vulnerable are different publics to space weather impacts – e.g. are some more susceptible due to the types of service they use / rely on? Is there any evidence of people taking action to reduce their susceptibility or increase their resilience to any space weather impacts? If so how?
- **Space weather mitigation:** would members of the public be willing to pay for space weather risk mitigation measures for key services e.g. air travel / communications / satellite navigation systems?

3.1. Engaging members of the public and other stakeholders

Objective 1: To engage the public and other stakeholders in developing this work, including enabling members of the public to ask questions and develop conversations with space weather stakeholders.

MATERIALS DEVELOPMENT PROCESS

The development of materials was a key part of the dialogue process. Space weather is not a commonly understood phrase, and it involves a unique mix of things happening millions of miles away with the potential for very localised impacts affecting people's everyday lives. It was therefore extremely important to develop materials that guided participants through the learning process and towards in-depth discussion and opinion forming, without overloading them with too much information or jargon.

The Oversight Group (OG) was closely involved throughout the materials development process, starting with a face-to-face review of initial draft materials and continuing with detailed comments on further materials as these were developed for workshops 2 and 3. OG members contributed numerous photographs, videos and graphics for use in the dialogue materials.

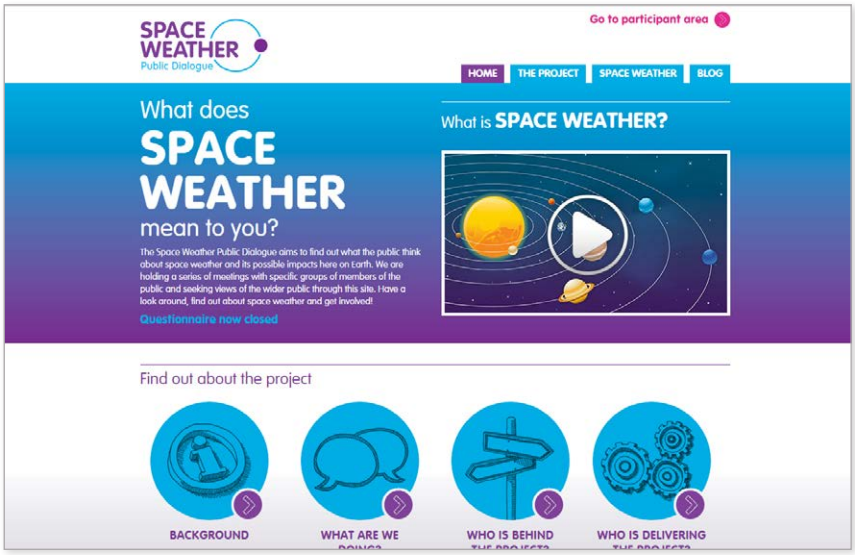
The first stage in the development of materials was to develop a strong but simple branding. This was applied to the majority of materials used in the workshops and online. A project website was developed to enhance the overall level of engagement and provide the project with an online presence, alongside a twitter feed. See Appendix 7 for more detail of the online activity.

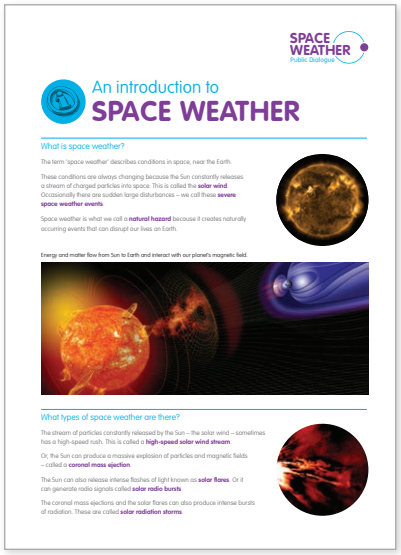
Early on in the process it was agreed that a short animation outlining some space weather basics would be a useful medium to enable initial engagement with the topic – this was posted to the website and shown to participants early in the first set of workshops. Other materials for the public workshops were developed in line with the process planning, in three steps to align with the three workshop stages:

- Workshop 1 materials focused on learning – including factsheets and worksheets to encourage basic discussions about space weather and its impacts.
- Workshop 2 materials focused on exploration – including scenarios designed to elicit deeper discussion about resilience and response, and a list of potential options for investment.

- Workshop 3 materials focused on conclusions – options raised in earlier workshops were discussed by members of the public and specialists in partnership.

See Appendix 9 for a complete list of materials developed for the public dialogue. The materials are designed to be adapted and used after the dialogue, in future discussions and communications, and will be passed on to STFC following the close of the project.





DEVELOPING A DIALOGUE BETWEEN MEMBERS OF THE PUBLIC AND SPECIALISTS

The process used a range of engagement methods, designed with different levels of interaction between members of the public and specialists in mind. See Appendix 6 for a summary of dialogue participants at each workshop. The evaluation report, expected to be published in early 2015, will provide an independent assessment of the dialogue process.

Dialogue workshops. This was the mechanism designed to elicit the strongest level of interaction between members of the public and specialists. The workshop structure involved a mix of presentations, working tasks, games, conversations and distillation of key messages, with workshops tending towards members of the public and specialists working together to develop conclusions as the process moved towards workshop 3 and the stakeholder summit. See Appendix 5 for more detail on the workshop methodology.

Specialist reflection:
"I've been really impressed with how engaged participants were, and really enjoyed talking with them about what their views on space weather are."

Online forum. The online forum was designed to enable members of the public and specialists to interact between workshops (see Appendix 7). There was very limited participation in the forum. This could be for a number of reasons, for example: not having any more questions to ask of specialists; not feeling motivated to engage in further discussion outside the workshops; feeling less comfortable with online interaction that with face-to-face interaction, and so on.

Representative online survey (i-omnibus). The i-omnibus took place between 26th and 30th September 2014, and involved 1,010 people representative of adults aged 16–75 in the United Kingdom. It asked questions about basic space weather knowledge, resilience and communication. See Appendix 8 for the overall results, and section 3.6 below for a summary.

Self-selecting online survey. The self-selecting online survey was open on the project website for anyone to contribute to, for the duration of the project. 71 people responded to the survey. A number of these respondents gave some indication of an existing level of knowledge or interest in the topic of space weather. This is perhaps not surprising given the self-selecting nature of the survey. See Appendix 7 for the overall results, and section 3.6 below for a summary.

The i-omnibus and the self-selecting online survey involved no direct interaction with specialists. This enables comparison of outputs between those resulting from an ongoing process of dialogue and those coming fresh to the process with no opportunity for discussion and clarification. See section 3.6 below for more discussion of the similarities and differences between outputs from the different sources.

The project website had a level of interactivity beyond the survey and participant forum, for example it included a blog and a range of downloadable information about space weather. See Appendix 7 for more detail on website statistics and structure.

See Appendices 4–7 for more detail on the overall dialogue process.

KEY MESSAGES

See **section 3.7** for key messages from participants and the project team.

Responses to the dialogue findings from stakeholders and observations from evaluators are explored in **section 4** of this report and in the **evaluation report** respectively.

3.2. Developing and gauging public understanding

Objective 2: To develop and gauge public understanding of space weather, its impacts and the resilience of civil society.

EARLY DISCUSSION OF SPACE WEATHER AND ITS IMPACTS

In the first round of workshops, participants watched an animation describing basic information about space weather and its impacts, followed by presentations providing more detail.

Participants were asked to consider specific impacts of space weather on themselves, their community, and wider society in relation to electricity, satellites, communications, aviation and other transportation. They were generally keen to start talking about impacts and 'how bad could it be'. Although most focused on negative impacts, some respondents talked about the increased level of face-to-face interaction and strengthening of communities that they said often happens in situations of uncertainty or disruption. There was surprise from some at the range of impacts, while others felt the consequences of impacts would depend on how long they lasted for.

> **"What's the worst case scenario? How bad could it get?"** Edinburgh participant, workshop 1

> **"Some unforeseen positive consequences too – electricity going down and Dunkirk spirit.[7] And notion of communities coming more allied to each other. Also less pollution if less planes."** Reading participant, workshop 1

> **"We're not living in some local 1950s gather round Dad's Army[8] – people do often live in isolation now. I don't live in a bad neighbourhood of Reading but I think it has to happen before people are spurred to respond. I think people would be 'I've got my stuff sorted and I might like to think I would help you but in fact I'll push you to the side to get to the water in the supermarket!'"** Reading participant, workshop 1

Discussions about personal impacts tended to focus on the disruption to everyday appliances or activities – for example lights, heating, alarm clock, freezer, TV, kettle, making phone calls, undertaking daily chores. Other possible impacts such

7. Dunkirk spirit: "The spirit of the British public pulling together to overcome times of adversity." (Ref: Wikipedia)
8. Dad's Army: a sitcom about the British Home Guard during the Second World War.

as isolation in rural communities were mentioned, although some felt rural communities would be better prepared for this kind of event.

> **"Smaller communities tend to know each other so can help each other better (that's my opinion anyway). More ready to chat and acknowledge other – easier to help out."**
> Wrexham participant, workshop 1

> **"I suppose if you're in an isolated place already you might be more prepared already. If you live on an island and you know there's only one boat a day."** Edinburgh participant, workshop 1

> **"When we had the snow in our area people knocked on doors to check on the old people."**
> Reading participant, workshop 1

Community impact discussions in many cases led quickly to the discussion of vulnerable people and the need to look out for specific groups such as elderly people, as well as friends, family and neighbours. The impacts on schools, shops and businesses (including online businesses) as well as systems such as traffic lights and streetlights were raised by a number of participants. In Wrexham, several participants suggested they would feel safer in a rural community rather than a city such as London during a severe space weather event, for example because of the possibility of crime and looting, and some participants in Edinburgh also raised questions about civil unrest. It is worth noting there was no specific specialist input with respect to civil unrest.

Specialist reflection:
"My overall impression is that the general public need to have more of a perception of all the risks they face and what they should do to be prepared."

> **"The long-term effect on the economy of power cuts, people not getting to school, banking system going down, schools shutting down, hospital etc"** Wrexham participant, workshop 1

> **"I think sometimes we're so dependent on things that Plan B doesn't come up at all these days. Take electricity for example, you can't imagine not having it for 3 days it would be chaos, but this happens in Africa, no lights, you have to cope, they already have Plan Bs. We take a lot of these things for granted. It's like mobile phones have been there forever but we didn't have them that many years ago."**
> Edinburgh participant, workshop 1

Discussions about wider societal impacts tended towards essential services such as transportation, hospitals or the military, and systemic effects on communication, food distribution and industry (e.g. financial loss), as well as some concerns about safety and security. Aviation in particular was one topic where the societal impacts were often felt to be potentially much worse than the impacts on individuals.

Overall, it seemed easier (as might be expected) for participants to focus on the impacts most relevant to their everyday lives. This might account for the tendency to focus on disruption to electricity supply rather than satnav and other impacts.

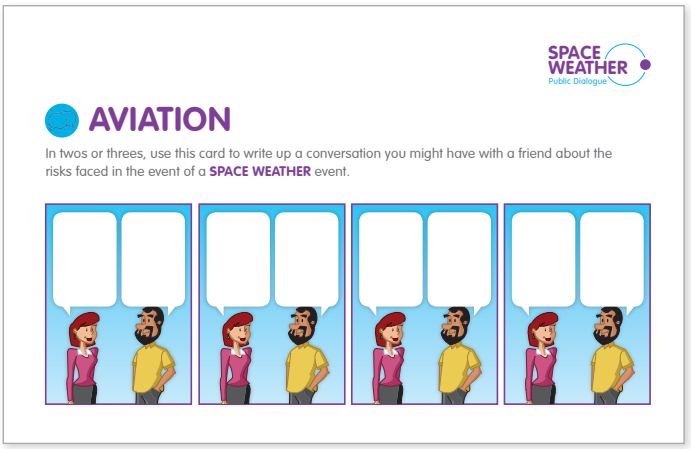
RISK AND RESILIENCE

In workshop 1, participants were shown a film outlining the concept of risk and risk appetite, a second film about the difference between risk and hazard, and a presentation about risk and space weather.

In twos or threes, participants used a cartoon strip template to create an imaginary conversation between two people discussing the risks to electricity, satellites, communications, aviation and other transportation.

Many of the conversations generated by participants focused on the general sense that there could be impacts caused by space weather, with some implying that these effects wouldn't necessarily be that bad and others moving towards specific preparation or response measures that could be taken by individuals.

Also in workshop 1, participants were asked to consider how various parties might prepare and respond to a severe space weather event, and were introduced to the concept of resilience. They discussed the response of individuals, communities, companies and governments, in particular exploring actions before, during or after a severe space weather event, responsibilities, and the type of help that would be needed.



"Who is responsible to let everyone know what's happening – for informing, for preparations, for educating?" Reading participant, workshop 1

"Who is responsible for reporting the detected solar events to the global community? Rather than country-by-country is there one body that collates and communicates?" Wrexham participant, workshop 1

Overall there was a wide range of messages from the discussions, including:

- Society has an increasing reliance on modern technology and on electricity.
- People need to keep calm and pull together as a community.
- There is a responsibility amongst individuals and communities to look after vulnerable people or groups.
- There are a number of actions individuals can take to prepare, including: volunteering; stocking up on food, water and candles; charging electrical appliances or buying wind up radios and solar chargers; having emergency numbers to hand etc.
- People need information to help them understand what is going on and cope both during and after an event, including knowledge of the role of their local resilience forum.
- Concerns about civil unrest and the need to be protected.
- The Government should provide guidelines for companies about contingency planning.
- Companies and governments have a responsibility to assess the risk and put in place contingency plans.
- There is not much individuals can do, and people will step up if needed.
- It could be difficult to get people to take this seriously.

Specialist reflection:
"There was a recognition of the need to have some personal resilience – I generally get a sense in everyday life that people look for someone to blame rather than taking personal responsibility – the attitude in the workshop was refreshing."

"They [companies] should have a strategy and plan in place. With back-up generators and equipment." Wrexham participant, workshop 1

"Government needs to be the hub that information is fed through to all the services and decides how they should run." Wrexham participant, workshop 1

"And it's not just government and companies – it's us as individuals and what we can do." Reading participant, workshop 1

At the beginning of workshop 2, participants discussed the homework they had been asked to undertake between the workshops:

'Talk to your friends about the possible impacts of a severe space weather event. Ask them: what might you do in the event of having no electricity for 24 hours; what do you think would happen if there was no satellite navigation system working?'

A number of participants had discussed space weather with friends and family, while others had undertaken some of the other suggested challenges such as turning off phones or electricity. Those people talking to friends and family said there was a range of reactions, from complete lack of interest, to a barrage of questioning about space weather and its possible impacts. A few people turned off their electricity for a while but tended not to last for more than a few hours. One or two turned their phones off, while others said they didn't want to, for example because they used it so much. This in itself is interesting, and reflects a number of comments about the level of reliance we have as a society on electricity and technology.

> **"We are already well prepared for loss of electricity, we always have plenty of practical things on hand – candles, wood, food etc and we can't really think how we might be more prepared."** Wrexham participant, workshop 1

> **"I did try to forego the electricity, but didn't last long. I needed a shower. 3 hours."** Edinburgh participant, workshop 2

> **"I did it the other way and made a list every time I used it – often same thing over and over – kettle, light switches etc. There were certain times of day you use more."** Edinburgh participant, workshop 2

Other participants undertook a twitter survey, kept a record of how much electricity they used, spoke to their workplace about contingency plans, and talked through a preparation and response plan with their children. A couple of people had undergone power cuts between workshops and described their experience of coping.

KEY MESSAGES

See **section 3.7** for key messages from participants and the project team.

Responses to the dialogue findings from stakeholders and observations from evaluators are explored in **section 4** of this report and in the **evaluation report** respectively.

3.3. Improving awareness

Objective 3: To consider how to improve public and stakeholder awareness about space weather and its associated impacts.

HOW MUCH INFORMATION CAN MEMBERS OF THE PUBLIC HANDLE?

The answer to this question, based on this dialogue process, appears to be "quite a lot", but this was based on an intensive and iterative process of learning, checking and discussion. This is not a process that can be undertaken with every member of the public. This was recognised in the workshops, and there was extensive discussion about the kinds of communication processes and materials that might work in order to increase awareness and understanding among the general public – see section 3.5 below.

Specialist reflection:
"Although a complex area, attendees were quickly able to grasp the issues underpinning space weather. The ability of non-scientific people to engage with science is much greater than is usually assumed on this evidence."

> **"Don't talk about 'space weather events' – people just wouldn't care."** Edinburgh participant, workshop 2

"The thing is with these sort of discussions it completely depends who you are talking to about it. I wouldn't bother to explain it to my grandparents!" Reading participant, workshop 1

WHAT WORKS, AND WHAT STICKS?

A range of materials was used throughout the process, including visual materials such as the animation, printed material to convey information or start conversations, verbal presentations, and less formal discussion.

The analysis below suggests that this combination of materials led to a good overall level of learning and retention, although undoubtedly some materials would have been more useful to specific people that others depending on their learning styles and preferences.

"Some of the moving imagery was really helpful, some of the explanations about magnetism were good. I have a visual way of understanding things so that was really good."
Reading participant, workshop 1

There were relatively few observations from participants about specific materials, although there were some informal comments, for example, about the animation, space weather bingo, and other more interactive or visually engaging materials. Certainly those materials that contained a higher level of scientific or technical language required more time to be spent on them.[9]

In addition, when discussing communication and awareness later in the process, participants tended to favour those mechanisms that were more interactive and visual, as well as a drip feed of information over time through different mechanisms (starting at school). They tended to like awareness-raising activities partly because they were relatively cheap, but also because they helped to encourage increased personal resilience. However, they also made the point that communications have to be based on sound data.

"Perhaps in the normal weather forecast you could start to drop in little bits/phraseology about space weather." Edinburgh participant, workshop 1

"You want to be putting the Sky at Night on once a week instead of once a month or whatever it is, and using a hip dude to present it. There aren't enough programmes on the mainstream channels about something like this." Edinburgh participant, workshop 1

At the end of workshop 1, participants spent some time reflecting on what they had learned throughout the course of the day, and what else they still wanted to know. Participants' learning appeared to strongly reflect the information they had received throughout the day and the subsequent discussions. For example, participants said they had learned about:

- Specific types of space weather.
- The fact that space weather exists at all, and that it could affect us.
- Specific types of impact.
- The range of possible impacts from small or contained to large or wide ranging.
- Wider systemic or ripple effects and safety implications.
- The difficulty in predicting severity.
- Individual action and community preparedness (either existing or potential).
- The need for education or information, and the role of local or national government in helping to prepare, respond and inform.

In workshop 2, it became apparent that many participants had talked to friends and family about space weather and had therefore passed on some of the information they had received in the first workshop. Some participants commented that the process of talking to others about space weather helped it to stick in their minds.

Early in workshop 3, participants took part in a quiz to check back on their knowledge about the science of space weather, its impacts, and resilience. Between them, participants had a generally good recollection of specific facts, although in some cases needed prompting from the specialists present in the workshop.

9. See the evaluation report, once available, for further specific comments on the dialogue materials.

Members of the public taking part in workshop 3 were also asked about the messages that had stuck with them now that they were towards the end of the process. They highlighted the following points:

- Common consequences – the idea of preparedness for a range of events with similar impacts.
- Resilience – we are not used to extremes in this country. Also those areas that might be more vulnerable might also have a naturally higher level of resilience.
- Terminology – space weather suggests a Dr Who[10] scenario and is not necessarily helpful (e.g. alternative phrases might be solar storms, solar impacts, solar effects).
- It starts with education – talk to kids about space weather or preparation for emergencies.
- Space weather and its effects are not easy to predict.

It is also interesting to note that a number of words and phrases introduced early in the dialogue were in regular use by participants towards the end of the process – for example space weather, resilience, Carrington event, coronal mass ejection. This resonates with the idea – which came up a few times across the workshops – of drip-feeding information to people in a repeated manner, so that they become familiar or even comfortable with the terminology and the ideas around topics such as space weather.

WHAT KIND OF INFORMATION DO PEOPLE WANT?

At the beginning of workshop 1, participants were shown a short animation about space weather, followed by a presentation on the science and current knowledge of space weather from one of the specialists in attendance at each workshop. This was followed by at-table discussions of questions arising as a result of the animation and presentation, using the prompts who… what… where… when… why… how…?

Questions covered a range of topics from the science of space weather to how society might prepare for, respond to, and communicate severe space weather events. Questions arising from the three workshops included:

- Predicting space weather: how do we know it is happening; how far ahead can we predict it; who monitors it?
- Communicating a severe space weather event: how is a predicted event communicated with others?
- Location of space weather events: where will events happen; who will be affected; will certain locations be affected more than others?
- Speed of space weather events: how quickly do events reach Earth; how can we tell how fast they are travelling?
- Regularity: how often do severe events happen; when is the next one likely to occur?
- Science of the Sun: how does the Sun work?
- Past occurrences: is there evidence of these events happening in the past; what were the impacts in the past; is it a bigger problem now?
- Links to Earth's climate and solar cycle: is there a link between space weather and global warming; what is the effect of the solar cycle?
- Range and length of impacts: how will it affect us; how long for?
- Specific impacts: a range of questions, including the dangers of radiation and radio interference.
- Why worry: what is the risk; why is this so important?
- Preparation and response: how can we prepare; how should we respond?
- Roles and responsibilities: who is taking action now; who will pay?
- Communication with members of the public: why should the general public be informed; when would they be informed; who would communicate with them?
- Purpose of the space weather public dialogue: why are we discussing this; what will be done with the information gathered here?

> **"When would we get notice these things were going to occur – fortnight? Week?"**
> Reading participant, workshop 1

> **"If something bad happens does it affect the whole world or just parts?"**
> Wrexham participant, workshop 1

10. Dr Who: a UK-produced TV programme dealing with issues of time travel, space travel and extraterrestrials.

"I don't know how reliant we are on air freight for food stuff. Is it just that we wouldn't have any bean sprouts?! Or would it actually matter?" Reading participant, workshop 1

Specialist reflection:
"This is interesting because it hints at the impact on farmers/ suppliers in other countries whose livelihood depends on airfreight of fresh food and flowers to Europe."

The range and number of questions generated after an introduction to the basics about space weather indicates that just having some knowledge about what something is and the fact that it could impact us quickly leads to people wanting to know more. Exactly what participants wanted to know varied within and between the workshops, but broadly focused on some key questions:

- Why do I need to know about it?
- How will it affect me and others?
- How likely is it?
- Does it link to other things I already know about?
- How will we know when it's happening?
- What can or should we do about it?
- Who is responsible for communicating, preparing, responding, funding?

One area of discussion that kept cropping up at the workshops but didn't get resolved was the dilemma around what kind of information to provide. Some people said that if they heard that a space weather event might happen (and assuming they hadn't been through this process) they would want to know more about what space weather is, while others said they would just want to know what to do about it, or how to prepare and respond.

We also tested this idea with the i-omnibus participants – see results in 3.6 below.

"TELL US HOW IT IS" VERSUS "DON'T SCARE PEOPLE"

The issue of what to tell people also crossed over with discussions about trust – participants suggested, for example, that being told there would be impact 'x' without being told what was causing it could lead to distrust and suspicion.

When discussing the dilemma of giving people full and frank information versus scaring them, participants tended to say that they would rather have all the information, but also highlighted the need not to scare people and the risk of a 'crying wolf' scenario. Several pointed out that having been through this process they didn't feel overly worried or panicked. The importance of not worrying people was raised, and participants often referenced the media as a potential source of panic.

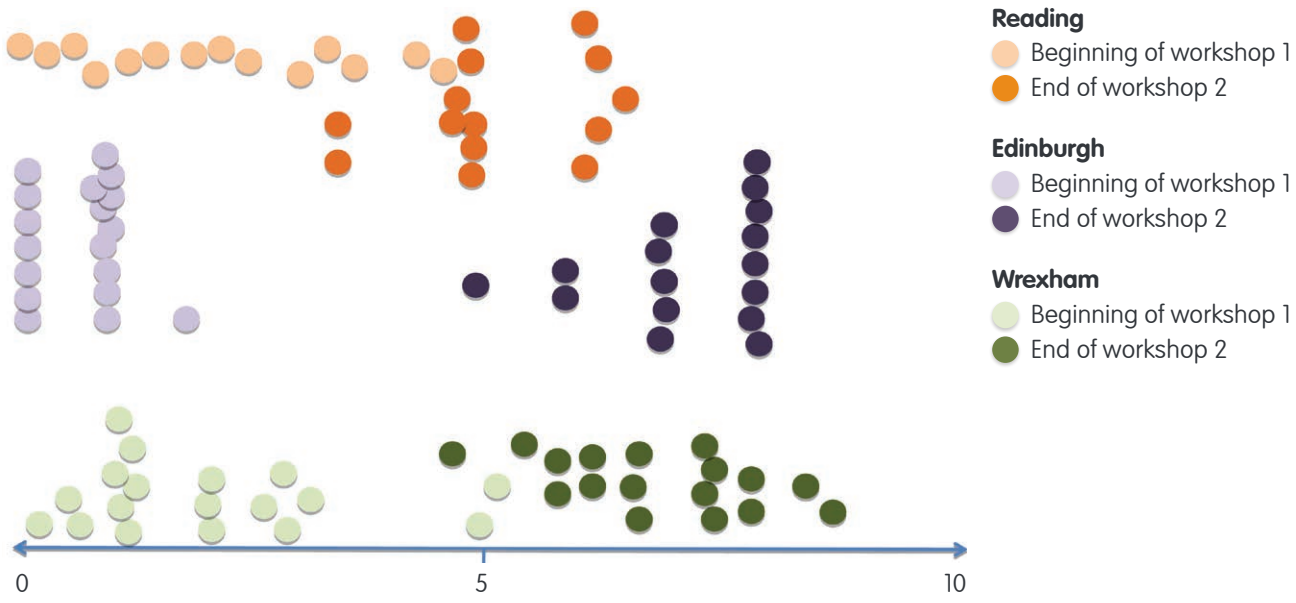
"Knowledge is power – because we know what it is now, we're not frightened by it."
Edinburgh participant, workshop 2

"There's a responsibility to communicate this with the proper facts, but the media don't necessarily report it in the same way – that affects how it's dispensed and communicated across the county. Need to make sure there's not scare-mongering." Edinburgh participant, workshop 1

SHIFTS IN ATTITUDES AND UNDERSTANDING

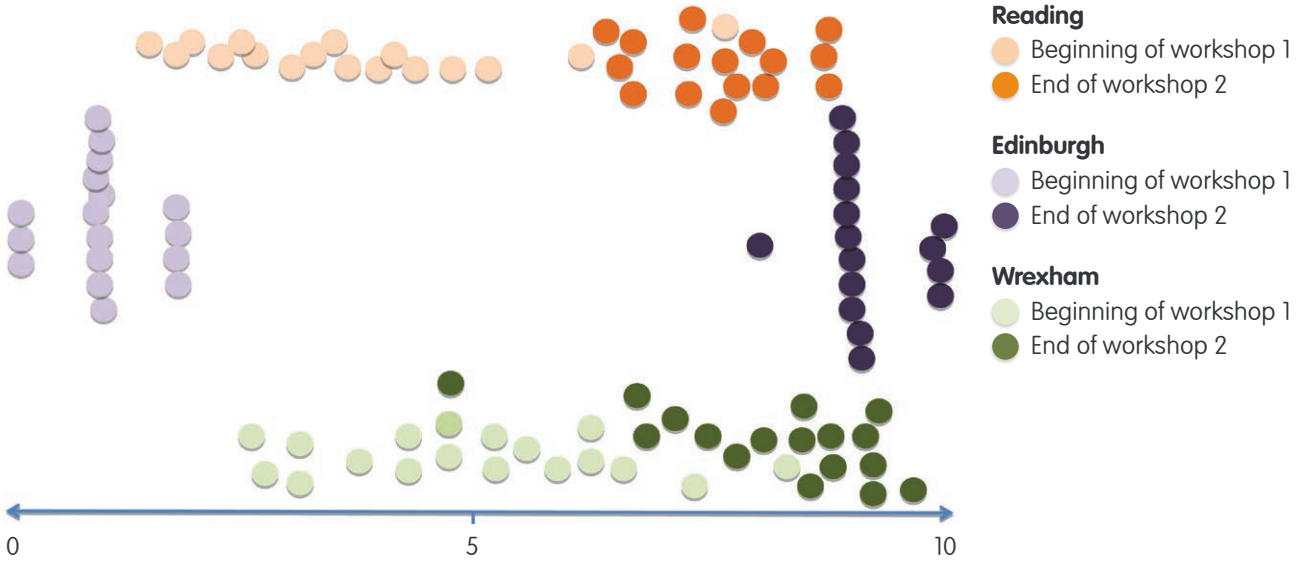
In order to gain an overview of baseline knowledge and attitudes, we asked participants three key questions as they arrived at the workshop. These questions were repeated at the end of each of the second workshops.

Question 1. How much do you think you know about space weather?
(0 = nothing, 10 = everything)



At the beginning of workshop 1, participants in all three locations tended to place themselves towards the bottom end of the scale (0–5), especially in Edinburgh. This suggests overall low levels of knowledge or awareness. It may be that recent news coverage of space weather events led to higher awareness amongst some people, as well as the possibility of 'groupthink', or association of the word 'weather' with other types of weather. At the end of workshop 2, there was a visible shift or bunching towards the middle to high end of the scale (4–8), suggesting the workshops had an impact on participants' overall level of knowledge about space weather (though being wary of a possible bias towards participants saying what they think the project team wanted to hear).

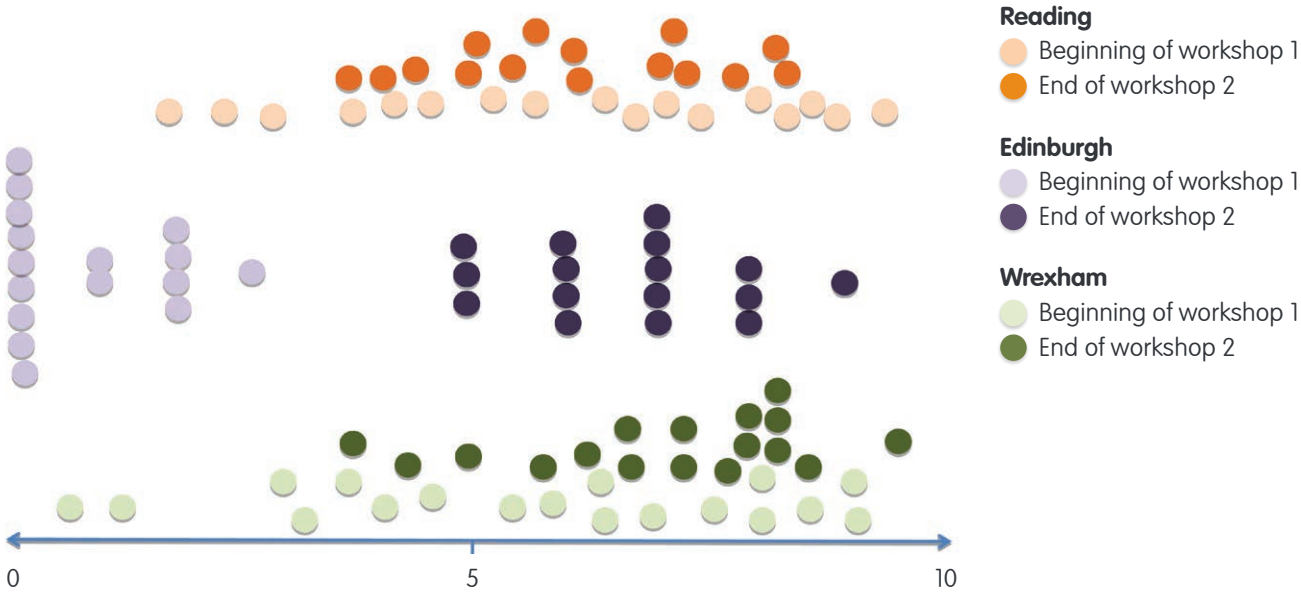
Question 2. How aware are you about the possible impacts of space weather on your everyday life?
(0 = not at all / don't think about it, 10 = extremely aware)



At the beginning of workshop 1, participants in Edinburgh placed themselves towards the very bottom of the scale, while those in Reading and Wrexham placed themselves largely between the 2–6 area. Aside from the potential for existing knowledge about impacts, it is possible that two words in the question – 'prepare' and 'severe' – may have influenced participants to respond to the question towards the higher end of the scale, as preparation for any type of severe event might seem like common sense. Again, this spread may be because of recent media coverage, because of 'groupthink,

or because of the association with 'weather' and its impacts, such as flooding. At the end of workshop 2, the vast majority of participants placed themselves between 7–9, suggesting an increase in awareness as a result taking part in the workshops – this is perhaps to be expected given the level of repeated exposure to information about space weather.

Question 3. How strongly do you feel about the need to prepare for a severe space weather event?
(0 = not at all strongly / don't think about it, 10 = very strongly / it's really important)



At the beginning of workshop 1, participants in Edinburgh again tended to place themselves towards the very bottom of the scale, while those in Reading and Wrexham were spread right across the scale. At the end of workshop 2, there tended to be a spread between 4–9 across all locations.

> **"But we only need to know that if we know what it does to us. And people generally don't understand it. Like climate change – it's a fear/panic thing, it's instinct. And people don't take that seriously. We only need to know if it's going to affect something in our lives."**
> Edinburgh participant, workshop 1

> **"You have to tell them – otherwise people will make up their own explanation. Every time there's panic it's because government hasn't told people what's going on."** Wrexham participant, workshop 2

> **"Everyone I spoke to had to have the whole thing explained – they didn't understand the subject at all."**
> Wrexham participant, workshop 2

KEY MESSAGES

See **section 3.7** for key messages from participants and the project team.

Responses to the dialogue findings from stakeholders and observations from evaluators are explored in **section 4** of this report and in the **evaluation report** respectively.

3.4. Roles and responsibilities in mitigating space weather impacts

Objective 4: To determine how far members of the public think the Government and companies should go to mitigate space weather impacts.

REACTIONS AND ROLES: RESPONDING TO A SEVERE SPACE WEATHER EVENT

In the second set of workshops, participants discussed two scenarios – one describing the early stages of a severe space weather event, and one describing an event that has been ongoing for three days.

Scenario 1. Participants broke into groups to discuss the following scenario, with some taking the 'individual' role and some taking the 'emergency responders' role.

Short-term scenario: individuals

It's mid-March and the weather is still cold. For the past two days you have heard rumours that there is going to be severe space weather, but no-one is sure what that means. The BBC weather report mentioned it but said that there wasn't much information and advised people not to panic.

You have also heard that a work colleague travelling from Asia via the US has been stuck in China because of problems affecting planes flying near the North Pole.

When you get home from work, the lights go off. It's getting dark, but you try to see if any of your neighbours have more information. One local radio ham tells you that he hasn't been able to use his shortwave transmitter to communicate.

Please answer the following questions:

Q. How would you feel if the power hadn't come back by the morning?
Q. What would be the aspects or problems that most concerned you?
Q. What five key actions would you take to effectively deal with the impacts?

Short-term scenario: emergency responders

It's 5pm in mid-March and the weather is still cold. You are a group of emergency responders from four different organisations in the region (e.g. Wrexham County Borough Council, North Wales Police, Wales Ambulance Service, Scottish Power Energy Networks). Early this morning you were advised by the Met Office that a geomagnetic storm is heading for Earth and there is the risk of a major event. The Met Office now confirms that the storm is going to hit Earth.

Divide into pairs, each pair should take on the role of one of the four emergency responders mentioned above. Discuss the role of your responder organisation and what their priorities would be in the 20 minutes before the geomagnetic storm struck and during the next 14 hours.

The pairs come together again and answer the following questions:

Q. What would your organisational priorities be?
Q. What five key actions would you take to effectively deal with the impacts?
Q. Is there anything/things that would need to change to enable you to respond effectively in a space weather event?

Among those taking the perspective of **individuals**, there was a general feeling that people wouldn't panic straight away, but would start to worry as time went on, although some said they would be worried straight away or said that in particular more vulnerable people would be likely to worry.

There was some sense that the level of worry might also depend on what information people had been given beforehand. This was combined with uncertainty over the level and nature of that information that is required to inform people without causing panic.

Several people commented that the situation would be more annoying than concerning, at least initially, for example because of the lack of ability to have a shower or boil the kettle. Others commented the situation might provide a good opportunity to reconnect with others or to improve community spirit.

The actions people discussed were strongly focused on three things: contacting relatives or neighbours, particularly more vulnerable people; trying to find out what's going on, with comments including looking outside, trying to use the Internet, calling the power company, and going to a local meeting point, notice board, police station or council offices; and stocking up supplies or ensuring sufficient water and food. Others talked about the need to lock the door for security, and other specific actions such as filling the bath with water and making sure babies were warm.

Participants discussing the role of **emergency responders** described their expectations of the role of the different agencies as follows:

Council:

- Coordination and informing.
- Making sure people have the necessary supplies.
- Advising vulnerable people (who may not have web access).
- Arranging meetings in the local community / holding a public forum.
- Putting posters up.
- Driving a car around with speakers.
- Having a contingency plan in place.

Specialist reflection:
"Attendees often talked about what more they could do to prepare for emergencies generally, and how communities could work together to improve resilience – acknowledged it wasn't just the Government's job."

Police:

- Public safety.
- Reassurance and communications.
- Ensuring adequate staffing levels.
- Visiting communities.
- Making sure response times are good.
- Having PCSOs on the street.
- Knowing vulnerable people and checking on them.

NHS:

- Communication.
- Having an incident plan.
- Pulling in extra staff / cancelling staff leave.
- Switching on back-up generators .
- Switching off non-essential equipment and cancelling non-emergency procedures/appointments.
- Outreach to people being cared for at home.
- Ensuring sufficient supplies.
- Liaising with local GPs and walk-in centres.

Power company:

- Contacting National Grid to see if they knew which areas would be affected.
- Making sure workers are on standby.

A common theme was communication and the need for a communications plan. From a more general perspective, participants said they would expect a set up like Cabinet Office Briefing Room (COBR) to be in place, filtering down to the local level. Essentially the message was "have a plan in place and communicate it". A few people said the message "don't panic" might cause people to panic more, especially if they did not know what was going on. Some people suggested having the armed forces on standby, though others thought that would be excessive.

> **"My first concern would be the food in the fridge. But obviously check if it was a community-wide power cut and not just a couple of places. Check on vulnerable neighbours. I would be concerned about not having heating if in March – it will be cold. And would you be able to communicate with family if they were far away?"** Edinburgh participant, workshop 2

> **"I would personally be wanting to know the time scale – will it last until lunchtime or long term. It's not knowing, having access to information and if nothing happens then start thinking about taking action and getting into a different mode."** Edinburgh participant, workshop 2

> **"I don't think society is as fragile as lots of people think – I don't think a couple of days will lead to chaos. Society has been around for so many years. The world changes but three days without electricity is not going to be the end of the world as we know it"** Reading participant, workshop 2

Scenario 2. Participants then discussed the following longer-term scenario in which the event had lasted for three days. In each workshop, the group broke into two tables of members of the public, and one of specialists.

Longer-term scenario

The space weather event you discussed this morning has now lasted for three days. Three coastal areas in Scotland, one in Wales and two in England have seen their power supply cut because of the failure of transformers. Replacement of the transformers could take between one week and four months*.

Some transport systems are still affected: air travel has been severely disrupted because of risks to communications and it is expected that there will be a ban on flights close to the poles until the risk of radiation is known to have ended. Communications at sea have also been affected so shipping activity has decreased substantially. Closer to home, 50% of global navigation systems are down, directly affecting about half of domestic and commercial car owners. Even those whose navigation systems are working are limiting the amount they use their cars because of fears that the navigation system could be disrupted or lack of fuel as panic buying leaves many petrol stations without supplies.

Households have seen their communications cut quite significantly. Not only has a small proportion of satellite TV channels been directly affected, some terrestrial TV stations that also depend on material from satellites are being hit.

Instructions for members of the public:

- You will be divided into two groups. Please work in pairs to identify issues that you think would arise. Write each issue/impact on a separate card.
- Once you have returned to your group, make a single list of issues and impacts for the whole group by going through each pair's list and filtering out impacts that duplicate others or that are unclear. You will be given a flipchart with a grid showing two scales: the number of people affected and the severity of the impact. Please place each of your impact/issue cards as appropriate on the grid.

Instructions for specialists:

- Working as a group, discuss the problems likely to arise from this scenario and what mitigation, if any, is likely to be in place. Write the issues or impacts that you identify on separate cards.
- You will be given a flipchart with a grid showing two scales: the number of people affected and the severity of the impact. Please place each of your impact/issue cards as appropriate on the grid. Put 'don't know'/needs more research/disagreement where appropriate.

There were a number of common messages around the potential impact on the 'essentials' – food, water, fuel and electricity – as well as a range of other comments including business impacts and mental health. There were a number of comments that specific issues – for example business or wider financial impacts – would be less at first, but with the potential to expand as time progressed.

Mitigation measures commonly focused on: planning; clear and timely communication; prioritisation at a local and national level; measures to aid systems resilience such as portable solar cells; and local mechanisms such as food kitchens, rest centres, transport sharing and providing essential supplies.

> **"Insurance – pre-emptive more robust insurance, particularly for smaller businesses. And then in the situation, immediate communication between insurers and businesses."**
> Wrexham participant, workshop 2

> **"Small businesses – some kind of government funding or relief to support small businesses or communities to rebuild."** Wrexham participant, workshop 2

> **"To the hospitals – it's back up generators, or solar panels that go straight into hospital not national grid. That's preparation."** Wrexham participant, workshop 2

PERSONAL RESILIENCE

Some of the workshop 3 discussions focused on personal and community resilience. The discussions about personal resilience focused on the idea of an emergency kit. Members of the public and specialists were asked whether they had some kind of emergency kit at home – a number said they did, while others said they had some relevant items in the house without necessarily thinking of it as a kit (possibly because items were distributed around the home). Only one person said they had got together a kit since being involved in the project, although a few said they had begun to think about it as a result.

There was no clear response to the question of whether an emergency kit would need anything different to deal with a space weather event as opposed to another cause, although one participant mentioned having a camera to photograph the aurora.

All participants agreed that the following items were essential in an emergency kit:

- Candles and/or torch (wind up)
- Bottled water
- Matches (one group specified waterproof)
- Essential phone numbers
- Battery or wind up radio
- Tinned food (and dried / packaged)

Other items deemed essential by one or two groups were:

- Copies of personal documents
- Baby wipes / hand sanitiser
- Cash
- Change of clothes / blankets
- Portable stove / BBQ / Kelly kettle
- First aid kit
- Pet food
- Water purification
- Can and bottle opener / corkscrew
- Medication

Specialist reflection:
"It was interesting and warming hearing a number of delegates discuss the need for the public to be better prepared and more self-resilient in the event of an incident and agreement this is not only for space weather but links in with other potential emergency scenarios."

Items that were generally deemed desirable rather than essential were:

- Pack of cards
- Board games
- Lighter
- Batteries
- Books
- Gas canister and gas stove

We also tested the topic of personal resilience with the i-omnibus participants [see 3.6 below].

> **"Most of the side effects seem to be things we should plan for anyway – lots of things could cause these effects. We should be prepared for it. I haven't seen anything that couldn't happen a different way."** Reading participant, workshop 2

> **"On a personal level people I spoke to were prepared for it – more on a community level. A lot of my neighbours are elderly – I felt the younger generation would cope better."**
> Wrexham participant, workshop 2

> **"I think the opposite – the older generation would cope better as they've been and done it. The younger generation have to have all the gadgets – there was a storm the other day and my son was panicking about his charger."** Wrexham participant, workshop 2

MAKING THE LINKS – COMMUNITY RESILIENCE

A key area for discussion identified as a result of the first two rounds of workshop was the gap between individuals in a local community and the local resilience forum (LRF), including overall lack of awareness about the existence of LRFs. Participants in workshop 3 spent some time discussing how this gap might be bridged.

One group mapped out current plans in one area for building links between the communities and LRFs. This consisted of: local forum engagement with a key person as an enabler; community emergency response plans involving key local agencies and volunteers; and wider involvement of, for example, safer neighbourhood teams and police community support officers (with knowledge of who is vulnerable in the local area). There was also mention of a 'phone tree' and local contact sheets, as well as the need for the local community to enhance preparedness so emergency responders can focus on vulnerable people.

The other two groups tended to focus on specific channels or mechanisms to aid linkages between the local resilience forum and local community. These included:

- Direct engagement from members of the resilience forum, e.g. at local fairs and other events, and use of ambassadors in the community.
- Public meetings, drop-in centres, dialogue or other events, to enable interaction and focus on the human element.
- Communication through local newsletters (school, church, online / website, community or village).
- Tapping into existing networks of trusted people – e.g. emergency first responders, community police officers, local (flood / snow) wardens, district nurses / caregivers, neighbourhood watch, local or community radio.
- Use of notice boards and posters.
- Making it clear how people find out about their local resilience forum (who, what, why).
- Link into local schools, e.g. via citizenship or equivalent activities / subjects.
- Put information on council tax bill and other publications.
- Provision of practical advice about what people can do (e.g. a box of supplies in case of a power cut).

KEY MESSAGES

See **section 3.7** for key messages from participants and the project team.

Responses to the dialogue findings from stakeholders and observations from evaluators are explored in **section 4** of this report and in the **evaluation report** respectively.

3.5. Informing policy, spending, responsibilities and priorities for action

Objective 5: To inform policy, spending, responsibilities and the priorities for action to mitigate space weather impacts.

"WHAT'S CHANGED AS A RESULT?"

A key question often asked in relation to public dialogue and other types of engagement is: "what's changed as a result?" One of the overriding principles for Sciencewise-funded dialogues is the presence of a 'policy home' – a specific policy area, decision, or topic within one or more organisations, which the outputs of the dialogue can plug into and ultimately inform. In the case of the space weather dialogue, these policy homes are multiple and diverse, as characterised by the range of organisations involved, and the mix of interests represented – research, communication, forecasting, strategy, risk, resilience and so on.

In order to influence policy, a project such as this requires three essential factors:

- An organisational willingness to take into account project outputs, as part of a wider process of amending specific policies and practices or developing new ones.
- Individuals representing these organisations who can act as champions for the project outputs and ensure they are taken into account by the relevant people.
- A robust process that delivers credible, high quality outputs.

It is up to individual members of the Oversight Group and other stakeholders to judge the credibility of the dialogue outputs, informed by their involvement in the project, this report and the thoughts of the independent evaluator. It is up to those organisations and individuals involved to use the outputs of the dialogue in a way that is appropriate to them. Informing policy isn't necessarily about changing the words on a page. It can take many forms:

- A personal or organisational desire to engage more with members of the public in future.
- Confirmation of existing plans or ideas, enabling a higher level of confidence in their delivery.
- Contradiction or challenge to existing ideas or plans, suggesting the need for further thought or discussion.
- New ideas, which may or may not be investigated further.
- Specific changes to policy, plans or principles.
- Identification of specific topics where there is a lack of consensus or potential concern, to be taken into account when developing future plans or policies.

Feedback from Oversight Group members and other specialists in the final dialogue workshop at Jodrell Bank reflected a positive view of their involvement in the project. They fed back to participants what they had learned so far. This included

a degree of surprise and reassurance at the strong level of public engagement with the topic of space weather and the desire from members of the public to know more, as well as the recognition of the need for personal resilience amongst members of the public and the need to link this up with local and national structures.

Members of the public present at the final workshop were asked what they thought should or would happen in response to their views. There was general agreement that the specialists would listen and give serious consideration to the views expressed in the dialogue, taking them into account in future plans and actions. However, one participant expressed scepticism and suggested they could just be ignored. Another was interested in the degree to which specialists were surprised at what they had heard, or whether they had heard anything completely new.

PRIORITISATION OF RESOURCES

As part of workshop 2, participants discussed a range of options for mitigation or research around space weather based on three categories: improved forecasting, increased resilience of existing infrastructure, and better information-sharing. Two groups at each workshop (six groups in total) discussed the options and they talked about how they would divide up a limited fund between the options. See Appendix 10 for the full outputs of this session.

Overall, there tended to be a higher level of resourcing put towards improved forecasting. However, this was at least in part due to the fact that many of these options were more expensive than those in other categories. Participants pointed out that it is important to be able to predict as it aids preparation and communication. There was also some discussion of sharing funding internationally.

Increased resilience of existing infrastructure – for example improved aviation communication – was generally met with two responses: isn't this happening already; and business should pay for all or at least some of the cost. Ensuring a sufficient stock of high voltage transformers was felt to be particularly important.

Participants liked the idea of investing in better information-sharing to increase awareness across businesses, the general public, and children. Positives included the fact that these options tended to be relatively cheap and that they linked to increased personal responsibility or resilience. The idea of informing parents via their children was also touched upon.

Specialist reflection:
"I was particularly interested in workshop 2 when observing the priorities game. It was interesting to see how the thinking changed as participants discussed and considered the different options available to them, and challenged each other continually on these. It was heartening to see the strong support for the observation and improved understanding / forecasting options as these indicate a good level of support for science by the public."

DELVING DEEPER INTO SPECIFIC OPTIONS

In workshop 3, the options discussed in the workshop 2 prioritisation exercise were added to with suggestions made by participants in previous workshops. The options for resourcing were then divided into research, systems or technological resilience, and options related to increasing awareness or understanding. These were discussed in turn with a view to gaining a deeper understanding of which options this group of members of the public favoured and why.

There were a number of detailed comments across the options discussed – see Appendix 10.

Broadly speaking, participants seemed more comfortable talking about research options than previously, saying for example that they wouldn't have been able to express an opinion without the knowledge they had. Better modelling and forecasting was felt by many participants to be an important part of our ability to prepare, as well as providing a solid grounding for any communications around space weather.

> **"Public information campaign is all very well but only good if you've got stuff to tell people."**
> Edinburgh participant, workshop 2

"More important to be gathering the data about what's happening and when it's going to happen, then you can be better prepared (i.e. better to understand what's going on)."
Wrexham participant, workshop 2

"I think it's important to be able to predict." Edinburgh participant, workshop 2

During the discussion about options for systems or technological resilience, participants were asked to comment on whether they thought specific options were high, medium or low priority. For many options (for example *'improve aviation communication systems'*, *'work with insurance companies to clarify their position on damage to technology or systems as a result of space weather'*, *'ensure alternative time signals to deal with GPS loss are in place'*) the response was a total mix of low to high priority.

Some options had a slight weighting. For example *'invest in more sustainable / resilient alternatives to existing infrastructure and systems (such as communications systems for emergency services, alternative navigation systems, alternative energy systems)'* tended to be classed as medium to high priority. This was the same for *'build in resilience to new buildings and development'*, and *'identify vulnerable areas (e.g. rural hospitals) and prioritise contingency plans/ measures in these places'*. Overall, there was a feeling that companies should pay for their own measures, and a slight leaning towards measures that enabled a systemic or innovative approach to resilience.

"Businesses have to take some of their own responsibility." Edinburgh participant, workshop 2

Participants discussed a range of communication options for increasing awareness and understanding of space weather. Overall, they liked the idea of increasing awareness, sometimes linking it to their own increased knowledge about space weather, for example saying it would reduce fear and improve resilience. Measures that were particularly favoured by participants included: adding space weather, or more generally coping in an emergency, to the school curriculum; and gradual and regular communication or drip-feeding, to familiarise people with the language of space weather. One group had a detailed discussion about including space weather in the weather forecast – this was generally met with a positive response, with the caveat that there would be a number of details to sort out (e.g. how often, with the forecast or general news, who should deliver it, etc). See Appendix 10 for comments on a range of other options.

Specialist reflection:
"There was a desire to understand more and to educate others – via accessible TV programmes and education material."

"It should be on the news, an announcement every 6 months – you know, make sure you have all these things in a bag under the stairs so you're ready." Edinburgh participant, workshop 2

"Could build it into the school curriculum – in an emergency when the power is cut off you call x,y,z. It wouldn't even have to be on space weather – even dealing with consequences."
Reading participant, workshop 2

"I had a discussion with the local high school about the subject and asked her opinion about discussing the issue and at what point it should be brought in. She said it would be fantastic to bring it into schools – kids love scenarios. And it's how she felt you start the preparedness, by introducing the subject and getting children thinking about it." Wrexham participant, workshop 2

KEY MESSAGES

See **section 3.7** for key messages from participants and the project team.

Responses to the dialogue findings from stakeholders and observations from evaluators are explored in **section 4** of this report and in the **evaluation report** respectively.

3.6 Reflections across strands of engagement

REPRESENTATIVE ONLINE SURVEY (I-OMNIBUS) HIGHLIGHTS
See Appendix 8 for full results

A summary of results: 1,010 people representative of adults aged 16–75 in the United Kingdom.

Question 1. How much, if anything, would you say you know about space weather?
The majority of respondents – 46% – said they had never heard of space weather, while 29% said they had heard of it but knew almost nothing about it. Just 5% said they knew a fair amount, and 1% said they knew a great deal.

Question 2. Which, if any, of the following have you heard of?
Respondents tended to be more familiar with some space-weather-related terms than with the phrase space weather itself. The most familiar terms (i.e. people had heard of them) were northern lights (92%), aurora borealis (75%), solar flare (70%) and solar wind (58%)

Question 3. Would you be more or less concerned if you heard that a power cut in your area was caused by space weather than if you heard it was caused by a storm?
Most respondents – 44% – said they would feel about the same. Of the rest, there was a tendency towards more concern for space weather (23% said slightly more concerned; 11% said much more concerned). 5% said they would be slightly less concerned if they heard the power cut was caused by space weather, and 3% said they would be much less concerned.

Question 4. For dealing with emergencies and disruptions such as power cuts, it is recommended that households routinely keep items such as the following in their homes: a torch, spare batteries, candles/ matches, tinned food, bottled water, spare medication, a battery-powered or wind-up radio, a list of contact details for friends/family/doctor and so on. Which of the following statements best describes how you would feel about unexpected power cuts which were to last the following length of time?
65% of respondents said they had adequate preparations in place for a power cut of 4 hours and would be able to cope with the likely disruption. This reduced to 41% for 12 hours, 26% for 24 hours, 12% for 2 days and 9% for 4 days. At the other end of the scale, 5% of respondents said they had little or no preparations in place for a power cut of 4 hours and would struggle to cope with the likely disruption. This increased to 9% for a 4 hour power cut, 18% for 24 hours, 37% for 2 days, and 48% for 4 days.

Question 5. Space weather is a term used to describe conditions in space, near Earth. It happens all the time at a level we might not notice here on Earth, but sometimes it can cause power cuts or other disruption to our communications, electricity, satellite and transport networks. Based on the information above, which of the following do you MOST want to find out more about?

Most respondents said they would want to know more about the possible impacts of space weather. This was followed by *'what you can do personally to prepare for the possible effects of space weather'*, then *'what causes space weather / types of space weather'*, and finally *'what others such as government and industry are doing to prepare for the possible effects of space weather'*.

Question 6. Where would you look to find out more about space weather?
By far the most popular response was online search engine, followed by Met Office website, television, scientific journals, online newspapers or news websites and weather forecast. The least popular responses were social media, local information points (e.g. town hall, library), blogs, conversations with work colleagues and local newspapers.

Representative online survey (i-omnibus)

i-omnibus questions relating to overall knowledge of space weather and familiarity with specific terms show that, while the term 'space weather' has little resonance with the general public, a number of associated terms are quite familiar. This could have implications for the idea of drip-feeding and familiarising people with the language of space weather, as it seems there may be some existing hooks to hang space weather off – for example 'northern lights' and 'solar flare.'

The level of concern from i-omnibus respondents tended to be slightly elevated for a power cut caused by space weather compared to one caused by a storm. However, 44% said it would be about the same. There could be a number of factors at play here, including unfamiliarity with the term space weather, other known impacts from storms (e.g. structural damage) and lack of external context.

The response to the question of personal resilience during a power cut over different lengths of time is as might be expected: the longer the power cut, the less prepared people feel. Based on the i-omnibus results, between the 12 hour and 2 day mark is the point at which the majority shifts from feeling they have adequate preparations in place for the length of time to having little or no preparations in place. The majority shifting from saying they could cope with the disruption (regardless of level of preparation) to saying they would struggle to cope happens at around the same point, pivoting around the 24 hour mark. This reflects comments from workshop participants about the importance of timescales and the need for information and practical support for impacted communities and individuals in an ongoing scenario.

The 'what kind of information' question was explored further in the i-omnibus, by asking: "Space weather is a term used to describe conditions in space, near Earth. It happens all the time at a level we might not notice here on Earth, but sometimes it can cause power cuts or other disruption to our communications, electricity, satellite and transport networks. Based on the information above, which of the following do you MOST want to find out more about?" [NB participants could select more than one option.] Impacts received the most attention – 44%. However, 28% of people selected causes and types of space weather, as well as 33% preferring to hear more about personal preparation and 25% selecting preparation from government and industry. This suggests that all of these aspects are important but that, perhaps where there is a message about the science of space weather, thought should be put into how to link this with impacts and preparedness.

The clear preference for a mechanism to find out more information about space weather is an online search engine. This has implications for the range and quality of information that appears on the Internet with respect to this topic. However, it is worth noting other relatively popular choices: Met Office website, television, scientific journals, online newspapers or news websites, and the weather forecast. In contrast to what many participants (particularly in rural areas) said, local information points (library, town hall) were not high on the list for finding out more information. It is worth noting, however, that workshop participants tended to talk about local meeting or information points as places to find out more information during, rather than before, a severe space weather event.

See Appendix 8 for the full results.

SELF-SELECTING ONLINE SURVEY HIGHLIGHTS
See Appendix 7 for full results

There were 71 respondents to the online survey. See Appendix 7 for a full breakdown of responses. Because these participants were self-selecting, they tended to have an existing level of knowledge or interest in space weather – 47.0% said they knew a lot about what space weather is, and 49.2% said they knew a lot about the possible impacts of space weather.

Most respondents were either not very worried or a little worried about the potential impacts of space weather on them personally and on their communities. The biggest worries tended to be about impacts on electricity (81.4%), communications (74.6%) and satellites (59.3%), with aviation and transport receiving less attention. Just 3.4% said they were not concerned about any of those impacts.

Respondents were asked what action they would personally take before, during and after a space weather event. Comments ranged from none, to contacting friend or family, preparing a grab bag or stocking up, disconnecting appliances, and watching the aurora. Information and communication were thought to be key to helping individuals cope during a severe space weather event.

Respondents were asked what action they thought their community would need to take before, during and after a space weather event. Key actions included care of the vulnerable, stocking up, ensuring mutual support or communication, and having a central meeting point. Again, information was seen as key, and one person mentioned that it would be valuable to have a community emergency group to help with coordination.

Respondents were asked what action they thought government (local or national) would need to take before, during and after a space weather event, as well as what they personally and their communities would need to help them cope. The role of local and national government tended to be seen as one of support and information, as well as action (effective response, have emergency services ready, provide leadership, have a strategy in place).

When asked what government (local or national) would need to help them cope, more resilient communities and reliable information sources or communications were seen as important elements.

Communication and contingency planning or risk reduction were commonly mentioned as important things for companies to do. Again, good up-to-date information was seen as important.

When asked, of all the things they had discussed, what they would prioritise, respondents cited a number of things, including communications and information, early warning, calm or assurance, and protecting infrastructure.

Self-selecting online survey

Respondents to the self-selecting online survey differed from those in the other two strands of engagement in that they were more likely to have existing interest or expertise on the topic of space weather. Aside from this point, however, their responses was broadly reflective of the kinds of comments coming from workshop participants. For example, electricity was highest on their list of impact concerns, with aviation coming bottom. And, like workshop participants, common themes included focusing on basic needs and the need for good planning and communication.

See Appendix 7 for the full results.

3.7 Key messages

Messages from participants to space weather stakeholders

Communicating the basics. Participants wanted clarity about what space weather is, how it might affect them and what remediation is already in place. There is a need for simple and consistent answers from government departments, agencies and other relevant organisations to the following questions:

- *What is space weather?*
- *How long could a severe space weather event last, what would the likely impacts be as a result and what can we do about it?* This could include, for example, a range of scenarios with suggestions for preparedness and actions in the event of an incident, including who to contact for help. Participants indicated their initial priorities would include contacting relatives or neighbours (particularly more vulnerable people), trying to find out more information about what is going on, and ensuring they had sufficient water and food.
- *How vulnerable is the UK?* Participants suggested that communicating uncertainty is fine as long as there is clarity over roles, responsibilities, current mitigation plans and contingency plans, i.e. who would do what.

There was some debate over the use of the phrase 'space weather' given the specific connection to the Sun's activity, though it was recognised that space weather is the commonly used phrase internationally.

Level of information. Participants said that they learned a lot throughout the process – for example that much of the information was no longer "beyond their comprehension". They wanted honest answers with respect to the consequences of a severe space weather event, but said that this should be in context – with an awareness of the ability of the media to inflate stories.

Mechanisms for wider awareness-raising. Participants came to the conclusion that wider awareness-raising activities among the general public are a good idea because they are relatively cheap and help to encourage increased personal resilience. They suggested there should be more communication about space weather, but that this had to be based on sound data.

Specifically, participants talked about drip feeding information. They said there should be a consistent low-level feed of information relating to space weather into the public domain, in order to familiarise people with the terminology and concept of space weather and reduce the chance of panic should a severe event occur. This should be non-threatening and interesting – for example focusing on already-familiar terminology such as 'northern lights' and linking it to more complex space weather language and science.

Specific suggestions to take forward were as follows:

- *Weather forecast.* There could be an occasional mention on national weather forecasts, possibly linking to further more detailed information. This could be similar to the pollen count, for example linking sighting of the northern lights with possible disruption to infrastructure.
- *Education.* There is an opportunity to work space weather or more general resilience content (e.g. responding to emergencies) into schools. Research Councils and communicators could work with schools to develop realistic scenarios and practical activities across a range of subjects such as science (magnetism, electricity), maths (data handling), home economics (cookery with basic supplies).
- *Broadcast media.* Besides potential mention on the weather forecast, suggestions included working with programme makers to develop innovative content relating to space weather or general resilience.
- *Communication resources.* Participants liked visual, interactive materials with consistent messaging. This raises the possibility of a library of resources relating to space weather or more general resilience.

Community resilience. Participants expressed a range of views about their own ability or that of their communities to cope in the event of a severe space weather or similar event. Some felt modern communities tended to be less resilient than in previous decades or that the UK as a whole is generally not used to extremes, while others felt their (rural) community is relatively well equipped.

Participants recognised the need to increase personal resilience in general, but stressed that personal action needed to come hand in hand with action from local and national government and emergency responders in terms of preparation, guidance and mitigation – increased resilience was seen as a shared responsibility and participants felt this should be communicated.

Participants made the distinction between community and local government, but did not know of the existence of local resilience forums (LRFs). Increasing the visibility of LRFs and their connections with local communities was seen as a good thing – to help members of the public understand what happens in an emergency situation and how they can prepare. More generally, improving connectedness and information provision at a local level was viewed positively, particularly with respect to helping vulnerable people.

For many participants, conversations increasingly centred on general resilience rather than being specific to space weather – for example the suggestion that measures should be taken to improve general resilience around events with common consequences.

Participants stressed the role of local and central government in informing people of events and relevant actions early, to help reduce both the level of systemic impact and the level of worry or panic among individuals and communities.

Systems resilience and the role of industry and governments. Participants recognised that better systems and technological resilience could have wide ranging benefits for individuals and society, but were concerned that the bill shouldn't necessarily always come out of the public purse. They suggested mitigation actions around aviation and power networks, for example, should be funded at by the relevant private companies, or in collaboration between the public and private sectors. Participants indicated that they liked measures with a systemic or innovative approach to resilience – for example developing more sustainable infrastructure with tools such as local solar generators and solar roof tiles.

There was a strong message that companies and governments have a responsibility to assess space weather risk, put in place contingency plans and communicate these. The idea of collaboration was discussed, with participants commenting that sharing information between agencies as far as possible was a good thing. Participants also stressed the need for local and central government to inform people of space weather events as early as possible, to help minimise the level of systemic impact and the degree of worry or panic among individuals and communities.

Forecasts, modelling and data. Participants recognised the value of forecasts and modelling as a tool to raise general awareness (for example getting people used to the idea of warnings and following up with further information about what actually happened), as well as a mechanism to assist in preparation and response to periods of adverse space weather. They expressed support for funding further monitoring and modelling systems, adding that sound data is an essential basis for reliable communication. This included support for a new monitoring satellite, with the caveat that costs should be shared – for example internationally, or between public and private sector. Participants also thought citizen science projects were a good way to engage members of the public.

Overarching messages. Participants were clear they expected their views to be taken into account in future plans and actions. They concluded that investment in research and forecasting, the resilience of technology and systems (such as power and communications systems), and increased awareness and understanding are all important.

Messages from the project team to space weather stakeholders and dialogue professionals

- Learning we have taken away from the public workshops in particular is not to shy away from enabling high levels of natural conversation to happen between members of the public and specialists, rather than having specialists in the room simply to answer questions and not express an overt opinion. This is caveated with the need to clearly brief specialists prior to workshops on how they express their opinion, and to build up to a process of more intense dialogue via sessions of structured learning and exploration of issues.
- The high level of input of the OG members and other specialists, and their willingness to engage in direct dialogue with members of the public, were key factors in the success of the project from the project team's perspective.
- We learned the value of allowing plenty of time for conversations between specialists and members of the public, and of using non-standard methods including cartoon strips, quizzes, game cards, scenarios and role-play, etc. We believe this contributed to a strong level of interaction between specialists and members of the public, and to a shared understanding of roles, responsibilities and needs between different participants.
- The credibility and quality of the public dialogue process is key if the outputs are to be taken forward and seriously considered by the relevant organisations. We would ask individual members of the Oversight Group and other stakeholders to make their own judgement on the degree to which this objective has been met, based on their own observations and those of the independent evaluators, and to let us know.
- Three questions were asked at the beginning of workshop 1 (see full results in section 3.3. above): how much do you think you know about space weather; how aware are you about the possible impacts of space weather on your everyday life; and how strongly do you feel about the need to prepare for a severe space weather event? Results suggested that participants coming into the process broadly speaking had a relatively low knowledge of space weather and its impacts, but were quite mixed in their views about the need to prepare.
- The iterative process of 'learn, check, discuss' – combined with a mix of visual, verbal, written and interactive materials – worked to bring members of the public to a point where they could sensibly discuss issues around resilience and resourcing in relation to space weather. This process can obviously not be undertaken with every

member of the public, but there are some more general messages from participants that should prove useful for future communications.

- There is no clear steer on the balance between giving people information about the science of space weather and about what they should do to prepare or respond to it. The preference towards one or the other varied across the group, and linked to conversations about trust in government and openness / transparency – overall, both were seen as important.
- There was a real sense from participants that they thought personal and community resilience was important, but that this had to go alongside strong support and communication from local and / or central government.
- Look at the outputs of relevance to your organisation and areas of interest, in particular the key messages from workshop participants. Consider whether these confirm or challenge your existing thinking, whether you have heard anything new, and what you will do as a result.

4. TURNING OUTPUTS INTO ACTION

4.1 Stakeholder summit

On 15th October 2014, members of the Oversight Group and other key stakeholders came together along with five members of the public who had taken part in all three stages of the public dialogue workshops.

The project team gave an overview of the process and findings, and members of the public fed back their main reflections to the group of stakeholders. Attendees then discussed four key questions in relation to the dialogue findings:

- What level of public awareness is needed?
- What is the appropriate level of preparedness?
- What new knowledge is needed?
- What are you planning to do as a result of the dialogue?

Messages emerging from discussions of these questions are summarised below. See Appendix 11 for the full transcript of the stakeholder summit.

4.2 Responses from stakeholders to the key findings

These are some of the messages emerging from the stakeholder summit in response to the findings of the dialogue.

PUBLIC AWARENESS

"Things we should bear in mind"

- The tolerance of members of the public will be affected by their understanding of the issue/problem.
- It would be good to have as much notice as humanly possible – three to four days is not yet possible.
- Understanding the diversity of impacts is important, e.g. weather effects beyond extreme scenarios, diversion of aircrafts.
- Levels of awareness – you have to explain what those levels are, e.g. terrorism alert – do you actually know what it means?

"Things we should consider doing"

- Raise awareness through multiple media channels, pitched at different levels and audiences.
- Develop positive media output to counter bad journalism, and e.g. focus on aspects such as the northern lights.
- Consider quick and easy education projects, e.g. jam jar magnetometers.
- We're not capitalising on opportunities to communicate better, e.g. during the recent possibility of strong space weather. Develop a library of strong images or graphics to use.

"Things that need further discussion"

- Including space weather in the general weather forecast.
- How do we get the information out, e.g. in relation to local resilience forums?
- We live in a country where extreme things don't tend to happen, so people aren't used to having to be resilient. How do you educate people?

LEVELS OF PREPAREDNESS

"Things we should bear in mind"

- At 24 hours it would be useful to be told there is a coronal mass ejection on its way, and then half an hour beforehand to know what it's going to do. That way people could change their behaviours (e.g. working from home) or be on alert (e.g. nurses).

"Things we should consider doing"

- Develop messaging around general resilience in a 'dripfeed' manner.
- Develop a consistent but realistic message, e.g. the Royal Academy of Engineering report – so that everyone sings from the same sheet, which is UK-focused and gives an accurate picture.
- Develop materials people can watch – videos, etc. Also a simple form of 'what's going on' to suit different types of learning styles. And remember every person who works in a business is a member of the public too.
- Work to clarity which types of areas will be affected and how big they are – this would be useful for planners.

"Things that need further discussion"

- What could / are we learning from elsewhere in the world?
- What do we mean by an emergency 'kit' and how do we ensure people have some form of one (e.g. this might just mean having the right selection of items around the house)?
- Consider innovative ideas such as a themed Ready Steady Cook.

NEW KNOWLEDGE

"Things we should bear in mind"

- Currently some industries are not inclined to admit this is a problem.
- There is great scope for improving modelling and measurements.
- The spacecraft up there at the moment are very aged and on their last legs. Funding for replacements is difficult as it tends to fall between science and operations.

"Things we should consider doing"

- A small amount of additional information slotted into the current education programme, specifically in high school. This could teach children not only about space weather but also resilience – so consider developing information packs schools can use.
- There is a general need for some materials around this so that schools and local resilience forums can pick this up. It needs to be accurate and good quality.
- Develop some more in-depth scenarios about what different types of space weather events might look like.

"Things that need further discussion / research"

- Predicting when a flare or CME will occur and getting information about the magnetic field of any structure heading towards Earth – these are two things we have almost no knowledge of.
- Understanding the effect on Earth's magnetic field and knowing which bit of Earth will be affected.
- We don't know the true cost of a severe space weather event so we don't know how much to invest. Effectively there is the need for a business case, but currently there aren't the numbers to put into this.
- More modelling of the degradation of electronic circuitry on the ground, and of concurrent effects.
- How do we to get this information into schools?

SUGGESTED ACTIONS OR COMMITMENTS

The following actions and commitments were listed by summit participants at the end of the meeting, either as thing they would take forward (as individuals or organisations), or things they thought other people should do in response to the dialogue findings.

Academia

- Think about what is needed for personal resilience and act on it! And find out who my local resilience team are.
- Ensure any of my research done considers the impact for operational space weather forecasting.
- Continue to tap interest of general public to help serve space weather science through citizen science initiatives.
- Work with partners to develop public engagement / (and) citizen science projects.
- Seek funding to develop forecast model at university / funding council level.
- Contact local schools to discuss talks / activities on space weather science including resilience.
- Consider how the findings of the project will strengthen the case for increased space weather enabling research.
- Prepare my emergency box at home!

Communicators

- Consider features about preparedness and social resilience.

Forecasters

- Seek additional funding for: economic study; broader range of engagement / education material; wider industry engagement.
- Enhance the space weather information on our website.
- Improve the ways space weather forecasts / impacts are communicated both to the public and business / industry

Government

- Discuss potential avenues for greater cooperation among local resilience forums in sharing of knowledge – best practice in general and on solar storms in particular.
- Discuss with colleagues the best form of delivery in communicating the risks of solar storms.
- Find better ways to put over messages on what we are doing to the public.
- Use results to inform case for investment in space weather missions.

Insurers

- Continue to raise awareness within the insurance community on space weather. It is not taken seriously at present.

Public

- Do my bit – prepare myself, and pass it on, not rely on technology as much.
- Have cash at home
- Have a hard copy address book.
- Continue working with local high school to increase awareness / teach about space weather, its impacts and general resilience.
- I would like to have feedback from the dialogue project and share information with others in school and community.
- Put together a pack.
- Talk to family and friends.
- Make a box with water, candles, cards etc in it. Not just my camping box. And find my local resilience forum.

Research Councils

- Ensure the final report is circulated to appropriate people within the organisation.
- Talk to colleagues about pushing toward UK network / group on avionic and ground based systems.
- Discuss how to contribute material to space weather "resource box" to increase public awareness.
- Try to find out how these results will be used by government, and how we might use them to create new funding for research and instrumentation.
- Better to define the framework for what the modelling and infrastructure needs are (based on the appendices).
- STFC and RAL Space community as a central point for resources, media, images, stories, etc.
- Sharing internationally with the contacts we have. There are a number of groups that would be very interested to see what we have done in the UK.

Resilience forums

- Include space weather in risks section of website.
- Feature space weather on community resilience campaign literature ("aware and prepared").

- The Local Resilience Forum will be developing a space weather emergency plan.
- Personally – put together household emergency pack.

Sciencewise
- Help to link the resilience work and lift it up a level to make a coherent story and a persuasive case.

4.3 What next?

This report will be published via a launch event in early 2015 and disseminated to a range of interested parties, including members of the public who took part in the dialogue workshops. All dialogue materials and website content will be handed over to STFC. STFC will make selected materials available for re-use in space weather communications activities.

In response to the dialogue findings, STFC led the development of a set of recommendations to facilitate action from government and members of the space weather community – see Call to Action at the beginning of this report.

Appendix 1
PROJECT BACKGROUND

What is space weather and why is it an issue for society?

> **"Space weather is a term which describes variations in the Sun, solar wind, magnetosphere, ionosphere, and thermosphere, which can influence the performance and reliability of a variety of space-borne and ground-based technological systems and can also endanger human health and safety"** [Koons et al., 1999]

Severe space weather is one of the highest priority natural hazards in the UK National Risk Register[1] and has the potential to disrupt many technologies critical to the functioning of modern society.

It arises primarily due to the Sun's activity, for example when extreme sunspots or coronal mass ejections generate adverse environmental conditions such as electromagnetic fields, high-energy particles, hot plasma, or changes in thermospheric density and composition. These can affect technologies operating in space, in the Earth's atmosphere and on the surface of our planet, including:

- Electric power grid – disruption and potential for substantial black outs.
- Pipes, railway cables – impacts on electricity flow/disruption.
- Trans-oceanic cables – impacts on electricity flow/disruption.
- Satellites – impacts to electronics, computer failures, memory loss, solar cell damage.
- Aircraft – enhanced radiation risks to passengers and crew.
- Avionics and ground systems – impacts on GPS, radar, signals.
- Radio communications – disturbance of radio waves.

Records show that a solar superstorm – now known as the Carrington Event – hit the Earth in 1859. Telegraph systems went out of order; telegraphers reported shocks coming from their apparatus; auroras were seen in the southern United States and southern Europe, indicating a storm of particles from the Sun. A similar storm today might, for example, result in power outages, expose aircraft passengers and crews to additional radiation, and affect global telecommunications through satellite and cable damage.

Evidence from historic events such as that in 1859, and later in 1921, is being drawn together with more recent experience from severe events in 1989 and 2003, in order to identify scenarios for future severe space weather events. But space weather science is recognised as a relatively young field. Severe space weather was included in the 2012 UK National Risk Register (NRR), and the NRR notes that significant work is required to better understand and prepare for the expected impacts of a severe space weather event.

Why talk about this with members of the public now?

Extreme space weather events are characteristically low probability, but with the potential for a high level of impact. We are currently in a seven-year period of solar maximum (high solar activity), which makes sunspots and coronal mass

1. The National Risk Register provides a government assessment of the likelihood and potential impact of civil emergency risks.

ejections, and thus a severe solar storm, more likely. However, as discussed above, our understanding of the science of space weather is currently limited, and we cannot be certain what the impacts of such an event would be.
The media and space science community are talking about space weather; new committees have been set up to discuss the topic and how to address it, as well as the emergence of a UK Space Weather Strategy. In December 2013 the Department for Business, Innovation and Skills announced a £4.6M investment in space weather forecasting, in order to *"help protect the technologies our day-to-day lives rely on".*[2]

A better understanding of how members of the public understand space weather, and perceive related risks and mitigation, as well as how to communicate the nature of these risks, would be both useful and timely. Outcomes of the public dialogue are expected to feed into the policies and strategies of numerous organisations.

In short, space weather is now firmly on the political and commercial agenda, both in the UK and on a global scale. Learning more about how the public perceives, reacts to and best understands space weather and its associated risks, as well as the potential impacts and responses or mitigation, will be key to informing effective policy and scenario planning on this issue.

> **"Space weather is a global challenge requiring coordinated global preparedness. We recognize space weather as a significant natural hazard risk with economic and societal impacts on key infrastructures and technologies including power grids, location and timing systems, aviation operation and security of satellites."** Joint Statement by Sir John Beddington, United Kingdom (UK) Government Chief Scientific Adviser and Head of the Government Office for Science, and Dr. Kathryn D. Sullivan, Deputy Administrator National Oceanic and Atmospheric Administration (NOAA) United States (US) Department of Commerce, regarding cooperation on space weather.

What do we know about public views?

There may be increasing public interest in space weather, but there are also issues with the way the media has covered this issue in the past, for example focusing on more visible but less damaging events.

Space weather has received significant attention in political, academic and commercial circles. For example the European Commission's Joint Research Centre held a two-day Space Weather Awareness Dialogue in 2011, bringing together 70 high-level representatives from national organisations and authorities, international organisations with assets possibly affected by space weather, operators of critical infrastructures, academia, and European Union institutions. However, there is no current public dialogue work already in place with regards to space weather.

Sciencewise's 2013 social intelligence paper *Public Views on the Commercial Application of Space* states: *"The last academic study on space-related technologies and public opinion focused on space tourism and was published over a decade ago. Satellites and the potential impacts of extreme space weather storms are an important part of the UK's national infrastructure. However this report found no evidence among the sources identified that the public are aware of space weather, or the threat that space weather storms pose."*

In addition, recent media coverage of flooding events and increased blackout risk in the UK are suggestive of an opportunity to build increasing public consciousness of some of these related issues.

2. www.metoffice.gov.uk/news/releases/archive/2013/space-weather-forecasts

Appendix 2

OVERSIGHT GROUP AND KEY CONTRIBUTORS

OVERSIGHT GROUP

- Mike Hapgood – STFC – RAL Space (Chair of Oversight Group and Project Lead on content)
- Sarah Smart – STFC – RAL Space (Project Manager)
- Alison Crowther – Sciencewise-ERC Team (Dialogue and Engagement Specialist for the project)
- Andrew Richards – National Grid
- Andrew Ryan – GO Science
- Chris Felton and James McBride – Civil Contingencies Secretariat, Cabinet Office
- Chris McFee – Department for Business, Innovation and Skills (BIS)
- Chris Scott – University of Reading
- David Kerridge – British Geological Survey
- David Wade – Atrium Space Insurance Consortium
- Jim Wild – Lancaster University
- Mark Gibbs – Met Office
- Mike Willis – UK Space Agency
- Poppy Leeder – NERC
- Robert Massey – Royal Astronomical Society
- Stuart Clark – freelance science writer

OTHER KEY CONTRIBUTORS

- Alan Thomson – British Geological Survey
- Alexi Glover – European Space Agency
- Alison Fleming – Leicestershire and Resilience Partnership
- Chloe Onoufriou – NERC
- Chris Frost – STFC – ISIS
- Clare Watt – University of Reading
- Ellen Clarke – British Geological Survey
- Gemma Kelly – British Geological Survey
- Helen Chivers – Met Office
- Ian McRea – STFC
- Marsha Quallo-Wright – GO Science
- Sophie Daud and Kirstie Rouillard – Cabinet Office
- Steve Berry – Staffordshire Civil Contingencies Unit

Appendix 3
KNOWLEDGE REVIEW (abridged)

The knowledge review undertaken for the Space Weather Public Dialogue is reproduced below. It does not contain: contents page, list of acronyms, list of references, and appendices. It also does not contain a number of figures and tables.

Executive Summary

Little is currently known about how members of the public perceive space weather[2] and its risks, or how best to communicate the risks, impacts and potential responses to an extreme space weather event.

The Science and Technology Facilities Council (STFC) and Sciencewise[3] have commissioned a project to run a public dialogue to help shape policies, spend and engagement on space weather for Government Departments and other organisations. The public dialogue will gauge current understandings of space weather and provide members of the public with information in order to explore changes in perceptions of risks and impacts.

The purpose of this knowledge review is to summarise background information on the likelihood and potential impacts of extreme space weather events and the ways in which these risks are managed, to inform the scope and design of the public dialogue. The review looks at how people obtain and make sense of information about space weather and other risks about which scientific knowledge is limited and which could potentially have far-reaching impacts.

The report is based on a review of current literature and interviews with space weather specialists working in different fields. All those interviewed are members of the Oversight Group (OG) for the Space Weather Public Dialogue project.

The review highlighted a number of issues which will need to be addressed in designing the public dialogue:
Areas in which understanding public attitudes, preferences and values will be particularly important to decision-making

- Both the public and the private sectors have a responsibility to understand and address space weather risks. What are the concerns, preferences and values of members of the public that government departments and agencies, industry associations and individual companies should take into account in prioritising efforts to address space weather risks?
- Government is the emergency responder of last resort. Is the UK Government's approach to managing national civil emergency risks (through a National Risk Register which identifies and assesses all risks in terms of the number of fatalities, illness or injury, social disruption, economic harm and psychological impact which they could potentially cause and regularly monitors to ensure that appropriate mitigation measures are taken) the right way to manage space weather risks? Should the Government be playing a more active role in protecting against space weather risks, for example through increasing funding for research in this area or through stronger enforcement of mitigation measures in both the public and private sectors?

2. 'Space weather' describes changing environmental conditions in near-Earth space. Magnetic fields, radiation, particles and matter which have been ejected from the Sun can interact with the Earth's upper atmosphere and surrounding magnetic field to produce a variety of effects. (Met Office: www.metoffice.gov.uk/publicsector/emergencies/space-weather/what-is-space-weather) Space weather is described in terms of 'events'. For the purposes of the public dialogue, a big or severe event is one that has a major impact in the Earth's atmosphere, rather than being a big event at the sun.
3. The Sciencewise Expert Resource Centre (Sciencewise-ERC) is funded by the Department for Business, Innovation and Skills (BIS). Sciencewise-ERC aims to improve policy making involving science and technology across Government by increasing the effectiveness with which public dialogue is used, and encouraging its wider use where appropriate to ensure public views are considered as part of the evidence base. www.sciencewise-erc.org.uk

- Currently there is not the knowledge or capacity to forecast space weather events as far in advance as weather on earth. Some space weather events can only be forecast with 15 – 30 minutes' warning. Scientific research could increase capacity to predict space weather events further in advance and to calculate how long it will take for the impacts of an observed event to reach earth. What priority should be given to space weather research versus increasing research into other risks such as flooding?
- To what extent should the Government be promoting cooperation and information sharing between public and private institutions in areas of activity that could be impacted by space weather events (e.g. Ministry of Defence, nuclear industry, public and private energy transmission systems, etc)?
- How should scientists work with industry and public bodies (such as the Ministry of Defence) to map the potential 'ripple effects' of space weather events? How important is it to recognise concerns about commercial or security sensitivities in these sectors?

Aspects which need to be considered when talking to members of the public about space weather risks

- It is possible to identify risk or 'fright' factors which affect the way that members of the public perceive different risks. Understanding members of the public's responses to the risk of a severe space weather event, and the way in which uncertainties about the probability of such an event occurring affect perceptions, could help to improve how they are communicated to the public.
- The language used by specialists to describe likelihood (for example, in terms of the 'return periods' for space weather events) is not easy for members of the public to understand. A further problem when talking about space weather risks is the use of ambiguous and potentially confusing language to describe scale and severity.

Potential questions for the public dialogue

- **Space weather forecasting:** how interested are people in the science of space weather forecasting? What do members of the public see as the value to society of improving capacity to predict when space weather events will occur?
- What are the **audiences for forecasts of space weather events**? Is it important that regular information about the probability of space weather events should be communicated in a way that is accessible to the general public? What would members of the public want to know in order to understand the likelihood of a severe space weather event? What do people understand by the Carrington event having a 1 in 100 year return period?
- **Space weather impacts and exposure:** what space weather impacts are people most concerned about / can see having the greatest influence on their daily lives? How do people engage with the notion of the ripple / cascade effect from space weather? To what degree do people appreciate / understand the interrelated nature of space weather impacts? Does this matter?
- **Space weather vulnerability:** how vulnerable are different publics to space weather impacts, e.g. are some more susceptible due to the types of service they use / rely on? Is there any evidence of people taking action to reduce their susceptibility or increase their resilience to any space weather impacts? If so how?
- **Space weather mitigation:** Willingness to pay for space weather risk mitigation measures for key services e.g. air travel / communications / satellite navigation systems.

1. Introduction

'Space weather' describes changing environmental conditions in near-Earth space. Magnetic fields, radiation, particles and matter which have been ejected from the Sun can interact with the Earth's upper atmosphere and surrounding magnetic field to produce a variety of effects.[4] Space weather is described in terms of 'events'. For the purposes of the public dialogue, a big or severe event is one that has a major impact in the Earth's atmosphere, rather than being a big event at the sun.

As well as space weather events which produce impacts in the Earth's atmosphere, there are occasions when particles or matter are ejected from the sun and although expected to have an impact on us, eventually miss the earth (referred to as 'near misses'), Monitoring this information helps scientists better understand space weather events and their frequency.

Little is currently known about how members of the public perceive space weather and its risks, or how best to communicate the risks, impacts and potential responses to an extreme space weather event.

The Science and Technology Facilities Council (STFC) and Sciencewise have commissioned a project to run a public dialogue on space weather. The purpose of the dialogue is to help Government Departments and other affected organisations, such as utility companies and insurers, to shape their policies, spending and approaches to involving members of the public.

The public dialogue will assess how members of the public currently understand space weather and will provide members of the public with information about space weather in order to explore how their perceptions of its risks and impacts change. The dialogue will also be an opportunity to create a number of scenarios for future space weather and discuss with members of the public how resilient the UK is likely to be.

This knowledge review is intended to provide background information on the likelihood and potential impacts of extreme space weather events on life on earth and the ways in which these risks are managed. This information will be used to scope and design the space weather public dialogue. The review was also intended to gather, analyse and synthesise information about how people obtain, interrogate and make sense of information about space weather and similar risks, i.e. risks about which scientific knowledge is limited and which could potentially have far-reaching impacts on people's lives. This will establish the context and starting point for designing the dialogue and developing dialogue materials.

2. Methodology

The scope and focus of the knowledge review has been informed by discussions with the project Oversight Group (OG)[5].

The methodology for the review involved the following steps:

- Expert interviews: given the broad range of relevant expertise on the OG, 30-minute telephone interviews were conducted with six members to explore the main issues relating space weather, the risks associated with extreme space weather events, the management of risks and public and stakeholder perceptions. Interviewees were also asked if there were any key perspectives missing from the list of interviewees or anyone else who should be contacted. Two stakeholders were mentioned by more than one interviewee and were contacted for more targeted information. For referencing purposes, the interviews have been numbered and are shown as I-1, etc. The list of interviewees and the interview questions are shown in Appendices 1 and 2 [not included in this abridged version].
- Document review: both the interviewees and the wider OG were asked to provide relevant documents and materials for the knowledge review and for the preparation of materials for the dialogue events. A large number of reports,

4. Met Office: www.metoffice.gov.uk/publicsector/emergencies/space-weather/what-is-space-weather
5. Meeting held on 10 February.

academic papers, media reports and grey literature were suggested. This source was further supplemented by Internet searches to fill in any gaps identified. Given the limited time available for the review, the team was guided in prioritising the review by the interviews and, in the case of the literature on risk perception, our own knowledge of the literature.

- Analysis and synthesis of the evidence: an analysis was made of interviewees' responses to each of the questions and key issues were drawn out. Key themes were also identified from the documents reviewed. The two strands of information were brought together and have been synthesised in the current report.

3. High impact low probability events

There is concern that the nature of technological and social development means that shocks in one area can have far-reaching knock on impacts in many other areas. Where big shocks expected to occur infrequently, they are referred to as 'high impact low probability events' (HILP)[6].

> *The globalization of production and optimization of supply chains have increased systemic efficiencies in the global economy but have exacerbated the speed and scope of contagion in the event of shocks. They pose particular threats to key industries – especially high-value manufacturing – and to the just-in-time business model. The consequences of HILP events spread rapidly across sectors and borders, often with second- or third-order impacts that are hard or impossible to predict.* [Lee and Preston, 2012]

Space weather risks fall into the category of 'high impact, low probability events' and can be considered to arise from unfamiliar or novel sources. This affects how members of the public perceive these risks and can lead people to underestimate the risks (McFee, 2011). While there is quite a lot of consensus within the science community over the likelihood and types of impacts that could be caused by space weather events, these can be presented in different ways which may emphasise or downplay their importance. The way risks are presented may reflect individual attitudes to risk in general and to different types of risk, as much as their scientific knowledge. Scientists themselves have different attitudes: when we asked interviewees, 'What are the impacts of space weather that keep you awake at night?', responses ranged from 'None' to 'All of them'.

Members' of the public's reaction to this kind of event is also less predictable as there is no prior experience to build on. However, it is likely that concerns about the disruption of patterns of everyday life will generate high levels of anxiety and the potential for social unrest. Exploration of how the public perceives and reacts to these high impact, low probability risks can help to improve how they are communicated to the public (McFee, 2011).

A Chatham House Report (Lee and Preston, 2012) identifies a number of specific challenges associated with the management of HILPs.

- In a global economy, the likelihood of 'economic contagion' is high: recent events such as the 2010 ash cloud from the Eyjafjallajokull volcano showed that key sectors and businesses can be severely affected by disruption to production centres and transport hubs, particularly if these last for more than a few days.
- Responsibility for risks and their management: different sectors of activity will be affected in different ways. It is within each sector that the capability must be developed to explore the implications of these impacts along a chain of users, so that problems can be addressed and precautions taken. But given the possible scale of impacts across sectors and across national borders, national governments clearly have a role to play.
- Beyond certain thresholds, governments are the respondents of last resort – they are often expected to step in and take charge of emergency response during major crises. [p 3]
- Prioritising and preparing for risks: *National risk management structures – based on classifying events by tiered levels of threat and implementing specific contingency measures – may therefore need to be reconsidered. Instead, senior leaders and decision-makers will need to develop and roll out overarching strategies which consider the full range of preparedness and response capacities, and establish clear frameworks for decision-making.* [pps 2–3]

6. These events are also sometimes referred to as 'high impact low frequency '(HILF), for example in some US studies on space weather.

Making decisions about how to address space weather risks involves discussing how to value and prioritise between the things that people want to protect. Involving members of the public in these discussions is vital in order to get a sense of the values held by different people, for example in different parts of the country and by people of different ages or social backgrounds.

Public dialogue provides a way to explore this kind of risk with members of the public in order to understand priorities and concerns and the values they are based on. Concerns about the disruption of patterns of everyday life could generate high levels of anxiety and the potential for social unrest. Exploration of how members of the public perceive and react to HILP risks can help to improve how they are communicated to the public (McFee, 2011).

One way of talking about unfamiliar events like space weather events is to draw analogies between space weather and other more familiar events. For example:

- Flooding: the severity of the event is associated with how long it lasts (the longer the event lasts, the more severe it is) and how long it takes for affected people or systems to recover once the flooding recedes. Similarly, the duration of the event and the time it takes to recover also determine the severity of a space weather event.
- Pandemic flu: this risk is top of the chart in the National Risk Register. The last event was in 1918, before most people alive today were born. But being prepared for the possibility of pandemic flu is generally seen as a good thing, even when the pandemic doesn't happen, e.g. in the case of Tamiflu.

Another factor that needs to be considered in relation to space weather is vulnerability. The technical systems we use today are more vulnerable to space weather; space-based systems like the Global Positioning System (GPS) have become part of our lives and this means that we need to reassess the impacts of space weather events.

Space weather events can take different forms and will therefore have different impacts on earth. Some of these impacts – like power going down – will be familiar to members of the public from other contexts. However, other impacts such as radiation storms or GPS failure are less familiar and it is important to think about how we talk to members of the public about this kind of event.

For the space weather dialogue, for example, it may be valuable in the context of the recent flooding, to understand members of the public's views on the importance of space weather risks compared to risks like flooding and how much should be spent on mitigation strategies and resilience. It may be valuable to explore with members of the public how Government compares and manages different risks and whether scientists should be learning from other fields.

4. What is the current scientific understanding of space weather risks?

Risk is a measure of the likelihood that an event will happen and of the potential consequences of that event (Scottish Government, 2011; Cabinet Office, 2012). This concept is illustrated in Figure 1. For some types of risk (especially risks associated with natural hazards such as space weather), data from historical analyses and numeric modelling can be used to estimate the likelihood of events occurring. The impact of a given event can be assessed on the basis of various parameters. For example the Scottish Government (2011) consider factors relating to exposure, vulnerability and value in the assessment of flooding impacts and Cabinet Office (2012) consider the number of fatalities, illness or injury, social disruption, economic harm and psychological impact in the assessment of civil emergency impacts in the National Risk Register (NRR).

This section of the knowledge review asks the question – what is the current scientific understanding of space weather risks? The purpose of this question is to provide a robust context and starting point from which the dialogue can be developed e.g. how does public perception of space weather risks differ from that of the science community? What are the areas of similarity and which areas differ? As such, this section is structured around the main components of risk assessment and management through the following sub-questions:

- **Likelihood** – what do we know about the frequency of space weather events? How reliable is space weather forecasting?
- **Exposure / impacts** – what do we know about the consequences of space weather events?
- **Vulnerability** – how vulnerable are systems and infrastructures that are exposed to space weather impacts?
- **Adaptive capacity / mitigation** – what can be done to mitigate and manage space weather risks?

4.1 LIKELIHOOD – WHAT DO WE KNOW ABOUT THE FREQUENCY OF SPACE WEATHER EVENTS AND HOW RELIABLE IS SPACE WEATHER FORECASTING?

In recent years, great progress has been made in understanding the solar processes that govern space weather (Krausmann, 2011). For example RAE (2013) provides a very useful summary of the causes of extreme space weather including details of the solar events that can cause, for example, high-energy solar energetic particles (SEPs) and coronal mass ejections (CMEs). Furthermore, space weather exhibits a climatology which varies with time e.g. days (caused by the rotation of the earth), the eleven-year solar cycle and longer periods such as the grand solar maxima and minima. There is also variation within this climatology i.e. on some days space weather events are more severe than on others (ibid).

Understanding this variability is crucial for forecasting space weather events. For example, there is general agreement that a major space weather event could happen at any time, though most big events would be expected to occur around the solar maximum (Krausmann, 2011). Minor solar storms[7] are considered to be relatively common. Crucially, for UK planning purposes, the return period[8] of a Carrington scale event[9] (i.e. the reasonable worst case scenario) is currently considered to be 100 years (RAE, 2013). The UK NRR, the purpose of which is to inform civil contingency planning over five year periods, suggests that the relative likelihood of a severe space weather event occurring in the next five years (from 2012) is somewhere between 1 in 20 and 1 in 2 (Cabinet Office, 2012 – see Figure 1). This is similar to the probability of low temperatures, heavy snow or heatwaves; the NRR considers that the impacts of a severe space weather event would be on a similar scale to these terrestrial weather events.

It is useful to examine how other risks are managed. Coastal flooding appears in the UK NRR as one of the two second highest risks for the UK, but one that is considered to have a lower probability of occurrence than severe space weather. The Government has a programme of flood risk management, which aims to reduce the likelihood and consequences of flooding. Local Resilience Forums are required to assess the risk of flooding and develop appropriate contingency plans. These arrangements are constantly under review. During the winter of 2013–14, there was coastal flooding in many coastal areas. Investment in flood forecasting and warning and in flood defences and the development of emergency planning and response processes meant that loss of life and damages was much less than in smaller events in the past.

[Figure 1. National Risk Register (NRR) – risks of natural hazards and major accidents – removed]

Although the understanding of space weather science is regarded as fairly robust, capacity to predict when a severe space weather event will occur remains low. There are several reasons for this. In particular, the fact that space weather manifests itself in multiple ways (see above) means that understanding of the extremes of these phenomena and correlations therein is often poor (Krausmann, 2011).

The US National Oceanic and Atmospheric Administration (NOAA) describes three event types:

- Geomagnetic storms: disturbances in the geomagnetic field caused by gusts in the solar wind that blows by Earth.
- Solar radiation storms: elevated levels of radiation that occur when the numbers of energetic particles increase
- Radio blackouts: disturbances of the ionosphere caused by X-ray emissions from the Sun

7. In this Review, as in much of the literature, the term 'solar storm' is used fairly loosely. In order to avoid confusion, it might be worth getting the views of members of the public on their understanding of the term.
8. An estimate of the likelihood of an event such as a storm, earthquake or flooding, to occur.
9. *'The Carrington event is by several measures the most severe space weather event on record. It produced several days of spectacular auroral displays, even at unusually low latitudes, and significantly disrupted telegraph services around the world. It is named after the British astronomer Richard Carrington, who observed the intense white-light flare associated with the subsequent geomagnetic storm.'* (National Academies Space Studies Board. 2008. p5)

[Figure 2. A summary of the timing of space weather effects on technologies – removed]

The effects of solar radiation storms travel at or near to the speed of light meaning that they will always be difficult to forecast as they reach earth so quickly (RAE, 2013): SEPs have an arrival time of between 10 and 30 minutes (Krausmann, 2011). This is illustrated in Figure 2. Conversely there is more time available for forecasting geomagnetic storms which take much longer (18–96 hours) to reach the earth (ibid). Indeed *"it is now possible to monitor and model the evolution of an earth-directed CME such that its arrival time at earth can sometimes be predicted with an accuracy of +/- 6–8hours"* (RAE, 2013 p.14). Despite this, forecasts of whether or not the CME will interact with the magnetosphere, causing a geomagnetic storm with significant impacts on earth can only be provided with a 15–30 minute lead-in time (ibid).

There are also issues with data availability for model development. One expert commented:

> *The available data goes back 20–40 years, which is enough to validate models for everyday space weather conditions (the daily, seasonal and solar cycle variations that scientists refer to as climatology). However, much longer datasets are needed to accurately validate models for extreme events. For example, for flooding the rule of thumb is that modellers need 500 station-years of data to estimate the 1-in-100 year risk. For flooding, it is possible to combine data from separate rivers to simulate 500 years' of data. This can't be done for most space weather work as we have good data for only one star, namely the Sun.'* [I-6]

Similarly, stakeholders at the European Commission Joint Research Centre (JRC) Space Weather Awareness Dialogue agreed that *"there is a lack of impact scenarios and likelihood estimates necessary for [space weather] preparedness".* (Krausmann, 2011.p.4).

This issue was borne out to a degree in the expert interviews. For example whilst experts acknowledged that space weather forecasting science is developing (see below) and that *"understanding the probability side is going well"* [I-3], there was also recognition that this is still a new area. This was illustrated by the fact that while the Met Office has been in existence for 155 years, it has only been developing a capability in space weather forecasting for the past two years. The issue of poor data on major historical events was also raised and one of the experts highlighted that the reasonable worst case scenario for a severe space weather event (i.e. the 1 in 100 year event as per the NRR) may be overly optimistic e.g. the return period of a Carrington type event could be shorter and/or the impact assessment could be wrong [I-3]. Another expert commented: *"Data based on the monitoring of space weather is very limited The frequency of conditions possibly leading to an extreme event is low: during the 5 to 6 years around solar maximum there will probably be 2–3 events a year whose effects are noticed. The majority of these will have relatively minor impacts, but any one of these could have a major impact. The statistics from past events can't tell us which event that will be."* [I-7]

Box 1. The language of space weather

The language used to talk about space weather events can be ambiguous and confusing for lay people. RAE (2013) uses the term 'extreme' space weather whereas Krausmann (2011) talks about 'major' and 'minor' events. In the UK, the NRR refers to 'severe' space weather. The use of concepts like return periods to describe likelihood of occurrence is also known to confuse members of the public.

The language of 'weather' may also be misleading. 'Solar storm', for example, is an undefined term that is used fairly loosely.

The challenges of finding accessible language to describe space weather risks will need to be considered in developing the public dialogue. For example, how important is it to find more precise terminology? Is there a risk that using ambiguous terminology could make the topic seem more opaque to members of the public?

Improved forecasting of space weather events is dependent on several factors:

- Better predictive modelling which in turn is dependent on more and better data, effective sharing of data and validation of existing models against improved data (Krausmann, 2011).
- Better understanding of the physics of space weather, i.e. the knowledge that underpins modelling. Key questions to be answered include: what triggers the launch of a CME out of the Sun? What triggers sub-storms and produces the magnetic variations that threaten the power grid, as well as displays of bright aurorae? [I-6]
- Changes in the culture and behaviour of public sector and commercial organisations, so that staff and directors are encouraged to find ways of overcoming obstacles to cooperation, such as concerns about security or commercial sensitivity.

The collation of space weather data is also heavily reliant on having the right space weather monitoring assets in place (satellites and missions) that provide *"continuous, timely and reliable information that addresses the needs of the end-users"* (Krausmann, 2011 p.7). There are numerous current and planned international projects to replace ageing space weather assets or put new assets in place, e.g. the European Space Agency's (ESA) Space Situational Awareness Programme plans to launch an L1[10] monitor in advance of the 2024 solar maxima (RAE, 2013).

Also, developments in forecasting are increasingly seeking to identify features that could be used to predict fast travelling space weather impacts (see above) before they happen. This would help to address the problem of space weather events that occur on earth within minutes of the activities on the sun (RAE, 2013), by giving improved lead-in times. In the UK, the Met Office is in the process of developing a space weather forecasting system and has a number of ongoing projects in this area (Met Office, 2014a). The aims of the Met Office's space weather programme are:

- To produce near real-time space weather nowcasts and short-range forecasts by developing existing empirical analysis and modelling techniques
- To perform research with more sophisticated physical space weather models to assess performance, and identify and reduce model errors
- To build an upgraded space weather forecast system based on more sophisticated models and assimilation techniques (Met Office, 2014a).

Box 2. Summary of key issues for the public dialogue in relation to current knowledge about the frequency of space weather events and the reliability of space weather forecasting

- Further research is needed improve capacity to forecast the occurrence of space weather events and their impacts. What priority should be given to this area of research in comparison to research on other risks?
- To what extent should the Government be promoting cooperation and information sharing between both public and private institutions in areas of activity that could be impacted by space weather events (e.g. Ministry of Defence, nuclear industry, public and private energy transmission systems, satellite industry, scientific research, etc)?

4.2 EXPOSURE AND IMPACTS – WHAT DO WE KNOW ABOUT THE CONSEQUENCES OF SPACE WEATHER EVENTS?

As outlined at the start of this section, the impact of a natural hazard event can be assessed on the basis of various parameters including the number of fatalities, illness and injuries, social disruption and economic harm. In this regard, the activities in space (e.g. the severe geomagnetic storms caused by a fast-moving CME) can have a range of different impacts depending on the specific nature of the activities and the value and/or vulnerability of the receptors that are exposed to their impacts. Section 3.1 and Figure 2 provide summary information on space weather activities and the way that these interact with spaced-based and ground-based systems and infrastructures to cause impacts. A more

10. The L1 orbit is located 1.5M km towards the sun – real time space weather data from this location can improve forecasts and warnings of solar storms (see Footnote 4 for a discussion of this term) as they travel between sun and earth (RAE, 2013)

comprehensive summary of the causes and effects of space weather can be found in RAE (2013). This section provides further information on what is known about the consequences of space weather events i.e. what is exposed to space weather effects and what are the key impacts.

Space weather can impact both space-based and ground-based systems and infrastructures (Lloyds, 2010; Krausmann, 2011; Cabinet Office, 2012; RAE, 2013). Figure 3 provides a visual summary of the systems and infrastructures that may be impacted by space weather. Key space weather impacts in a UK context (i.e. those identified in the NRR) are discussed below.

[Figure 3. Space weather impacts – removed]

Although the types of impacts of space weather can be described as shown, there was concern among a number of interviewees that knowledge is based on models which have been constructed on the basis of limited data which doesn't necessarily cover the biggest events:

> *We don't know what the impacts of the big event will actually look like – all impacts have been assessed on the basis of modelling and assumptions (though 1989 and 2003 events inform the models – this will give you good ideas of what some of the impacts are but you really need to measure the big event). The assumptions drive the model. Big events could be much bigger. The interconnected nature and unexpected nature of events [is a problem] – not so much in terms of what happens but the response to what happens.* [I-5]

Space weather impacts by sector

Power networks: dependent on the orientation of the interplanetary magnetic field (IMF) in the solar wind, fast-moving CMEs can cause severe geomagnetic storms (RAE, 2013). These in turn can generate large geomagnetically induced currents (GICs) through long, electrically conducting systems such as power grids, pipelines and signalling circuits potentially causing damage to transmission, distribution and generation equipment in electricity networks (Cabinet Office, 2012). In an extreme event it would be more likely that there would be voltage fluctuations. In the UK, National Grid is confident that it can manage this impact as it manages voltage fluctuations from other causes and has procedures and equipment in place to deal with them. However, if the disturbance were great enough, there might be temporary local power disconnections, experienced by users as power failure. Not enough is known about the potential impacts of space weather on voltage, so it is difficult to assess the likelihood and size of fluctuations. Experts consider that it would take a very large event to produce any fluctuations at all.

Another key concern with power network impacts is the potential for permanent damage to transformers as a result of large GICs. A very large space weather event has the capacity to damage high voltage transformers, each costing £3–4 million. Replacement of transformers is time consuming, typically 16 weeks, and the lead time for construction of a new transformer is 2 to 3 years[11]. In the case of National Grid, 'If enough transformers were damaged in an extreme space weather event, it could compromise National Grid's capability to deliver power securely to GB. Our current modelling suggests that large scale disruption is extremely unlikely. This is on the basis of assuming a very large Carrington-like event.'

Within the UK, the Scottish power grid may be particularly exposed to space weather impacts due to its proximity to the auroral zone. There are also concerns surrounding the increased development of renewable energy – as renewable energy sources are frequently located in more remote areas, the longer transmission lines can create the conditions necessary for enhanced exposure to space weather risks (ibid). The impact on power grids was highlighted in the expert interviews undertaken as part of this knowledge review as were some of the other impacts of GICs. Some of the wider impacts of GICs, such as the impact of induced currents in pipelines reducing the effectiveness of measures that slow corrosion rates (Lloyds, 2010), were not picked up in the expert interviews however.

Satellite services: space weather can disrupt satellite services in two main ways: through impacts on satellites themselves, affecting earth observation and imaging systems, and through impacts on radio links to and from spacecraft, including links for global navigation satellite systems (GNSS) and communications (Cabinet Office, 2012). Impacts on

11. Note that this information provided by National Grid indicates a longer time than appears in some of the literature: *'...the lead-in time for replacement can be significant e.g. as much as 12–16 months'* (Lloyds, 2010).

satellite services are a particularly significant issue due to the range of advanced modern systems / infrastructures that are reliant on satellites, to a greater or lesser degree (Lloyds, 2010; RAE, 2013). For example, satellites play a fundamental role in the delivery of communication services – the Global Positioning System (GPS) is very exposed to space weather impacts due to its reliance on satellites for accurate timing information. Whilst the Internet is generally considered to be robust in the face of space weather impacts there is a move to deliver some internet services via satellite (e.g. to cover areas where physical infrastructure is poorly developed including more remote / rural areas). This would expose some users of Internet services to space weather impacts (ibid). Road and maritime transport may also be impacted by space weather due to increasing reliance on satellite navigation though these sectors are considered to be less exposed than aviation which is discussed in further detail below (ibid). The UK Space Weather Strategy notes:

> *The most critical uses of GNSS systems are probably for timing rather than location. For example, precision timestamping is crucial to operation of global financial trading systems and in particular for automated trading – any disruption to this could have significant consequences on financial markets and the public trust in the safety and security of financial systems. Accurate timing is also crucial to phase control of large networked systems such as power grids and mobile phone networks. Location is nonetheless an important use of GNSS with location-based services increasingly permeating the economies of all countries.*[12]

Aviation: the aviation sector is exposed to several key space weather impacts. In particular, airlines rely on high frequency (HF) radio and satellites to maintain communications (Cabinet Office, 2012) as required by international aviation rules (Lloyds, 2010). Both of these communication methods can be disrupted by space weather with disruption being particularly bad for certain routes, especially transpolar routes as communications satellites are not accessible from high latitudes (ibid) although Canada is developing communications satellites for the Arctic [I-6]. Currently for these routes HF radio is the only feasible means of maintaining communication – in instances when HF radio is degraded by space weather, airlines are required to use longer routes to ensure that communications can be maintained, increasing journey times and fuel costs (ibid). Single event effects (SEEs) caused by space radiation during certain types of space weather event can corrupt data and software held in digital chips. Whilst this can affect electronics at ground level it is a particular issue for aircraft electronics (avionics) due to the greater intensity of radiation experienced by aircraft at cruising altitudes (ibid).

A different kind of impact is the exposure of air passengers and crews to increased levels of radiation (ibid). The EU Euratom Directive (1996) imposes requirements on the European aviation industry relating to the monitoring of aircrew members' exposure to cosmic radiation and the provision of information on the effect of radiation. In the UK the Civil Aviation Authority has issued guidance on the measures to be taken[13]. In the expert interviews, two of the interviewees highlighted impacts on aviation as concerns, referring to the international nature of aviation as a key challenge for risk management.

Valuing the damage caused by space weather events

Because of the uncertainties surrounding space weather impacts, it is difficult to estimate their economic cost to different industries or activities. Some of the reasons for this uncertainty include:

- Problems of commercial sensitivity: in some areas, for example in relation to satellite vulnerability, operators are unwilling to make information public in case it damaged confidence in their operations and therefore their commercial standing.
- Secrecy surrounding new technologies.
- Development of models: this is a new science and therefore still involves considerable uncertainty. For example, the British Antarctic Survey (BAS) has tried to develop a model for radiation impacts on spacecraft. Despite detailed negotiations with some 30 organisations working in this area, they were only able to get data from one company.
- Lack of data – in this case, data on the costs of damage to equipment or replacing that equipment.

12. UK space weather strategy – linking research to operations draft 8, 17 January 2013 (p 13).
13. Civil Aviation Authority: Aircrew Exposure to Cosmic radiation. www.caa.co.uk/default.aspx?catid=49&pageid=7094, consulted 19 March 2014.

The areas of impact described in the RAE report (2013) are:

- Electrical power grid:
  'Current assessments suggest that, in the worst case, a severe space weather event has the potential to cause local or even national power outages, and that power would be restored to most consumers in a few hours and days. It is difficult to estimate the economic impact of such power outages but, if they were to affect major population centres and their industries, it is likely to be several billion pounds (based on UK GDP of £7 Billion per day in 2011, source: World Bank).[14]
- Other geomagnetically induced current effects:
  - Pipelines and railway networks
  - Trans-oceanic communications
- Satellites: A typical communications satellite cost about U$250m in 2010[15]. The effect of space weather on spacecraft operations is illustrated by the outage in January 1994 of two Canadian telecommunications satellites in geostationary orbit.2 On January 20, 1994, Telesat's Anik E1 was disabled for about 7 hours as a result of damage to its control electronics by the discharge of electric charge deposited in the interior of the spacecraft by penetrating high-energy electrons. During the E1 outage, the Canadian press was unable to deliver news to 100 newspapers and 450 radio stations. In addition, telephone service to 40 communities was interrupted. Shortly after E1 was restored to service, its sister satellite, Anik E2, went off the air, resulting in the loss of television and data services to more than 1,600 remote communities. Backup systems were also damaged, making the $290 million satellite useless. It took Telesat operators 6 months to restore Anik E2 to service. The E2 failure is estimated to have cost Telesat $50 million to $70 million (U.S. dollars) in recovery costs and lost business.[16]
- Ionising radiation impacts on aircraft passengers and staff
- Avionics and ground systems: Transpolar routes flown by airplanes are particularly sensitive to space weather, in part because of Federal Aviation Regulations requiring reliable communication over the entire flight. (FAA Advisory Circular 120-42B, June 6, 2008, Extended Operations (ETOPS and Polar Operations). It is estimated to cost about $100,000 each time such a flight is diverted from a polar route.[17]
- Impacts on GPS, Galileo and other GNSS positioning, navigation and timing systems
- Impacts on radio communication systems

The United States' National Oceanic and Atmospheric Administration (NOAA) provides some estimates (in US$)[18]:

- Satellites are impacted due to both the radiation (for higher altitude) and increased drag (for low-earth-orbit) operations. The economic value of the satellite industry is well in excess of $100bn.
- Electric power grids experience the penetration of unwanted induced currents during strong geomagnetic storms. A National Academies of Science report (2009) estimated the impact of a space weather-induced grid collapse to be in the $1 trillion range.
- Commercial airlines cannot fly over the pole during solar radiation and/or geomagnetic storms. Communication may be blacked out and there may be impacts on navigation accuracy. Estimates of direct costs for reroutes to accommodate bad space weather go up from $100k per flight.

Mitigation of space weather impacts

Within the expert interviews and the literature there is specific reference to the interconnected nature of advanced modern systems / infrastructures and also the notion of a 'cascade' or 'ripple' effect in the event of a severe space weather event (Lloyds, 2010; Krausmann, 2011; RAE, 2011). This concept is illustrated in Figure 4 from the OECD's 'Geomagnetic Storms' report (2011), which shows the multitude of interconnections both within and between systems and infrastructures that could contribute to an accumulation of losses, particularly if baseline scenarios (i.e. the reasonable worst case used for

14. Hapgood and Rees (2013) UK Space Weather Strategy (Draft 8, 17 January 2013. 64 clean) p12.
15. Lloyds 360° Risk Insight, Space Weather: Its impact on Earth and implications for business, p11.
16. National Research Council. Severe Space Weather Events--Understanding Societal and Economic Impacts: A Workshop Report - Extended Summary. Washington, DC: The National Academies Press, 2009 p5.
17. Severe Space Weather Events - Understanding Societal and Economic Impacts – Workshop Report, National Research Council of the National Academies, The National Academies Press, Washington, D. C., 2008
18. From the US National Oceanic and Atmospheric Administration's Space Weather Centre – Frequently Asked Questions (www.swpc.noaa.gov/info/FAQ.html, consulted 15 April 2014).

impact assessments such as the NRR) are too optimistic (OECD, 2011; Krausmann, 2011). The issue of baseline scenarios being too optimistic was also highlighted in the expert interviews where one interviewee expressed their concern about:

> *"whether or not the assessment is wrong, i.e. the probability is actually higher or the assessment of impacts is wrong".*[I-3]

Cascade / ripple effects are a particular concern in relation to impacts on satellite systems (see above) due to many users of satellite based services – "space infrastructures [such as satellites] are of increasing importance as many services they provide, e.g. communication and navigation, are critical for society and the economy" (Krausmann, 2011 p.4). Lloyds (2010) provides a very useful illustration of the potential cascade / ripple effects that could arise as a result of space weather induced power grid failure e.g. in terms of impacts on fuel, food, water, sanitation, communications, medical / health, finance and transport services. It has been suggested that there are inbuilt constraints associated with dependence on diesel as backup power for many systems: there is a risk that key systems will only function until local diesel stocks run out. There is also potential for a cascade / ripple effect within power systems themselves e.g. as a result of a "cascade effect in which more and more systems are switched off leading to complete grid shutdown" (Lloyds, 2010 p.13). The Committee on the Social and Economic Impacts of Space Weather Events of the US National Academies has also published a useful illustration of the interconnections between different parts of the US economy which give rise to dependencies and facilitate the spread of ripple effects from a space weather event (Figure 5.)

[Figure 4. First and Second Order Critical Infrastructure Disruptions – removed]
[Figure 5. Connections and interdependencies across the US economy – removed]

Some concerns were expressed about the development of knowledge related to mitigation:

> *The impacts side [of space weather science] is emerging and still more work to do – this is challenging as it is reliant on [...] feedback from businesses in terms of their understanding of impacts in relation to how it would affect them.* [I-3]

One interviewee suggested that tracing the chain of impacts through systems and between systems is a priority for managing space weather risks:

> *Some of the things that could be done are to sit down with the systems that use GPS and look at what would happen if the GPS were taken out or there was an injection of an intermittent signal which would lead to a bad signal and to explore the implications of these impacts along a chain of users.* [I-7]

Some sectors and institutions are already assessing and taking measures to address space weather risks. Some examples mentioned are:

- **National Grid** has in place a range of procedures that would be used to minimise the risk in the event of an extreme space weather storm. Developments in the grid are not fundamentally changing the nature of space weather impacts on operations. There are two main things that could change the way space weather risks are managed: on the scientific side, getting better estimates of the likelihood and frequency of large scale space weather events could change National Grid's assessment of the likelihood of severe impacts. Secondly, better understanding of the possible effects of smaller scale events on the grid could indicate that these smaller events can cumulatively shorten the lifespan of high voltage transformers.
- **Maritime transport and the wider transport industry** is aware of space weather risks and is developing its understanding of how forecasting can help. The Met Office will be delivering forecasting to meet the needs of transport industries from April 2014.

Some sectors and institutions where space weather risks appear to be less recognised and little has been done in the way of mitigation include:

- **Satellite services:** current management of impacts on satellite systems is limited. Many satellite engineers are interested in finding out about the issue, so the resistance appears to come from senior management [I-6]. One interviewee said:

To a certain extent satellite operators are a bit resistant as they don't want to admit that this is one of the risks that they face – they tend to dismiss it as a non issue as they claim that satellites are resilient to SW impacts now. [I-1]

The problems caused by space weather to scientific satellites are recognised and discussed. It is hardly credible that commercial satellites built by the same companies to the same standards as scientific satellites do not suffer any of these problems [I-6].

- **Finance sector:** finance and banking use GPS high precision timing. Even very small reductions in the time taken for signals to travel between financial centres can enable faster computerised trading and add value. There is little evidence that the sector has recognised the risk posed by space weather events to these communications systems.

[Table 1. Mitigation of space weather impacts – removed]

Box 3. Summary of key issues for the public dialogue in relation to current knowledge about the consequences of space weather events

- A number of areas of activity are likely to be impacted by severe space weather events. The institutions and companies in each of these areas show different levels of awareness of and engagement with the risks.
- Widespread reliance on GPS, communications and energy systems contributes to a high level of interconnectedness and the risk on knock-on effects across society.
- There is currently a low level of understanding of the interrelations between risks.
- Some sectors are developing measures to anticipate and mitigate potential space weather impacts but there are many sectors where this is not happening, either because there is a lack of awareness of the risk or because there is unwillingness to recognise the scale of the changes required.
- What is the role of Government is driving action?
- How do members of the public view the severity of the impacts described? What would people see as the relative priority of different mitigation measures?

4.3 VULNERABILITY – HOW VULNERABLE ARE SYSTEMS AND INFRASTRUCTURES THAT ARE EXPOSED TO SPACE WEATHER IMPACTS? AND WHAT CAN BE DONE TO MITIGATE AND MANAGE SPACE WEATHER RISKS?

Vulnerability to natural hazards comprises issues relating to the susceptibility and resilience of the things (e.g. systems and infrastructures) that are exposed to the hazard (Scottish Government, 2011). Susceptibility is a measure of how prone to impacts particular elements will be during a natural hazard e.g. the elderly, frail or sick can be more susceptible to injuries or loss of life. Resilience is a measure of the ability of something to recover from a natural hazard e.g. businesses can be more resilient through the use of insurance (ibid). In terms of space weather, Lloyds (2010) define three strategies by which businesses can plan for / manage space weather risks: 1) building robustness in advance (i.e. resilience planning); 2) adapting operations when an event happens (i.e. mitigation and adaption); and 3) fixing problems when they occur when the first two approaches are not feasible given the specific circumstances.

Understanding how big space weather events could impact life and activities on earth involves forecasting changes in vulnerability as well as forecasting space weather. New technological systems, infrastructure and activities may be more vulnerable to damage caused by severe space weather events, for example if they require long pipelines. Perhaps more importantly, space systems have become part of systems on earth and we are dependent on them for many of our everyday activities.

A key issue identified from the expert interviews in relation to vulnerability and capacity for adaptation or mitigation is poor public and stakeholder understanding and awareness of space weather risks.

- In terms of businesses for example, this could manifest itself through limited incentives to invest in preparedness measures (either resilience or mitigation measures). Equally, if space weather risks are not on the public's agenda then there may be limited potential to pass these costs on to the users of these services.

- In terms of members of the public, the multiple ways that individuals will be affected depends on a variety of factors, from where they live to their area of employment. Other characteristics such as dependence on transport services could greatly increase vulnerability. One interviewee suggested that there could be problems associated with promoting public awareness of space weather risks because there are few mitigating actions that members of the public could take. Other interviewees disagreed and one pointed out that there are ways in which individuals can reduce their exposure to space weather risks, for example in terms of backing up electronic data [I-2].

Lloyds (2010) recognise that the ideal response to space weather risks is to build resilience into systems and infrastructures that can then continue to operate through severe space weather events. This sort of approach is already being implemented to varying degrees, especially within the space sector where space craft are typically designed to withstand space weather up to a high level (ibid). In terms of ground-based systems and infrastructures, power grid operators in Sweden and the UK have put in place measures to ensure that infrastructures can handle the space weather events of the recent past (e.g. the 1989 and 2003 events); there is concern as to whether or not these systems could accommodate a more extreme Carrington type (i.e. 1 in 100 year) event (Krausmann, 2011). Lloyds (2010) discusses a range of resilience measures that can be put in place to help ensure that GNSS, power grid, electronic, avionic and mobile phone systems are prepared for the impacts of severe weather. The key issue with all of these measures is the attached cost which may be prohibitive for some sectors.

5. What is the public's current understanding of risk more generally?

A great deal is known about the way that members of the public recognise, make sense of and respond to risks. In designing a dialogue process with members of the public about space weather risks, it is important to draw on this existing evidence.

5.1 HOW DO MEMBERS OF THE PUBLIC PERCEIVE AND RESPOND TO RISKS?

There are different ways of looking at how people perceive risks. Some start from the characteristics of the individuals and groups involved and explore how these characteristics affect perception. Another approach focuses on the characteristics of the risk and seeks to identify factors which make the risk seem more frightening or unacceptable. A third approach is to focus on the process of communicating and understanding risk. These three approaches are discussed in turn.

Characteristics of individuals or groups that shape perceptions of risk

There has been a change in the way that members of the public are viewed and understood in the context of risk communication. The 'public' is no longer thought of as a single monolithic entity, but instead as being comprised of different groups that identify with a variety of different attitudes that influence their perception and response to risk (Bennett 1997; Science and Technology Committee, 2011). This acknowledgement of different groups has helped to inform and change officials' views on risk communication:

> *"Public reactions to risk sometimes seem bizarre, at least when compared with scientific estimates …However, such reactions are not totally unpredictable, or even necessarily unreasonable."* (Bennett, 1997:2, Communicating about Risks to Public Health, Department of Health)

It is recognised that perceptions vary widely across different cultures and groups and can be influenced by a number of factors such as familiarity, control, vulnerability, timing, trust in authorities and social responsibility (Cabinet Office, 2012).

There is a range of factors that influence how members of the public engage with risk. These build upon the idea that members of the public do not form a homogeneous group and instead make up different groups of individuals with similar values and perspectives that affect risk engagement. Previous experiences, attitudes and values and social factors can all influence how individuals engage with risk.

Characteristics of risks that influence the how they are perceived.

The UK Department of Health (Bennett, 1997) identified eleven fright factors that make risks generally more worrying and less acceptable (see Table 2). Several of these fright factors apply to space weather and may make it a more worrying and less acceptable risk. The factors that apply to space weather are: involuntary, inescapable by taking personal precautions in some situations, arising from an unfamiliar or novel source and poorly understood by science.

[Table 2 'Fright' factors identified in the UK Department of Health's Pointers to Good Practice report – removed]

Space weather risks fall into the category of 'high impact, low probability events' which are, as the name suggests, relatively uncommon and can be considered as arising from unfamiliar or novel sources. As discussed in section 3 above, this affects how members of the public perceive these risks.

How the process of communicating and understanding risks affects perception

'Media triggers' can lead to particular stories on risk becoming more prominent (Bennett, 1997). The UK Department of Health (Bennett, 1997) identifies nine media triggers, two of which may apply to space weather: 'signal value' and high exposure. Extreme space weather events are likely only to be perceived by members of the public in terms of their impacts: the event itself is often invisible to the naked eye or only visible in some places (e.g. the aurora borealis). Adverse effects may be experienced as a sequence of knock on impacts, starting with the disruption of global navigation satellite system (GNSS) signals that can then impact upon aviation, offshore exploration etc. (Krausmann, 2011). This extended duration of the impacts over time can have a high signal value as one problem follows the other leading to heightened awareness and concern. This can turn the event into a major news story. The level of exposure to the risk is also important as it determines the level of interest and relevance of the risk to members of the public. A severe space weather event could impact the whole population of a wide area, reducing their access to communications and affecting basic services ranging from water supply and energy to banking services.

The traditional media are "crucial" in influencing risk perception of members of the public, despite the rise of social media (Lee et al., 2012: 23). It was found that the travel industry dominated the traditional media conversation in the aftermath of the 2010 ash cloud[19] and was preferred for quotes as opposed to groups such as scientists and air traffic control (Lee et al., 2012). However, social media users, such as bloggers, were more likely to analyse primary data sources and to quote scientists and regulators in their work. The relationships formed, between organisations dealing with risk and members of the public and related communities, before high intensity and low probability events are "invaluable in times of crisis" for engaging stakeholders (Lee et al., 2012: 26).

The level of public concern surrounding certain risk events can be amplified in the public's mind through government agencies (flood warnings etc.) but also through the media, information officers, cultural and social groups, and opinion leaders (Kasperson et al. 1988).

This social amplification process has been likened to the effect of dropping a stone into a pond, and suggests that public concerns about certain risks may be amplified by previous, sometimes unconnected events (Cabinet Office, 2003: 15). It is important for those involved in managing risks to bear in mind how communications about a risk event could be amplified both by the actions or inaction of a range of social actors (Government, media, social media, NGOs, religious organisations, etc) and by individuals' own experience and memories. . The social amplification model recognises the role of informal, non-internet social networks and considers the different pathways that may prompt the public to engage with risk.

Recent research suggests that members of the public believe that risks can be exaggerated by others: this is evidenced by the use of clichés such as 'crying wolf' or 'scare-mongering'. This also implies a judgement about the way that the risk is communicated. However, it seems that people sometimes feel that it is explicable and excusable to emphasise risks, whereas in other situations it is not. (Busby and Duckett, 2012) There is little evidence about what factors influence this judgement. Equally, little is known about the degree of tolerance that members of the public have for 'false alarms'. That

19. The ash cloud that spread across Europe in April 2010.

is, being warned about future risks which don't subsequently happen. This is an important issue for space weather, given that forecasting technology is currently not extremely reliable.

How members of the public currently understand space weather risks

The experts interviewed had limited knowledge of how members of the public understand space weather risks. There was a general feeling that the public have a little awareness of the wider 'ripple' or secondary effects of a severe space weather event and the potential for it to impact their daily lives.

Two of the interviewees suggested that the types of issues frequently brought up by the public will be driven by the media (e.g. where to go to catch good aurora, Armageddon type scenarios etc). One interviewee suggested that a lot of questions that members of the public have may relate to the nature of the risk, i.e. what do we mean by a 100 year return period for a Carrington event etc.

Media reports can lead to a social amplification of public concern around individual events and lead to additional, unpredicted adverse impacts. Media coverage of the Chernobyl explosion in 1986 amplified fears about radiation and may have "contributed to a sense of hopelessness in the population in the Ukraine and neighbouring countries" (McFee, 2011:23). This in turn led to additional secondary health impacts such as a rise in alcoholism and smoking in these areas (McFee, 2011).

While the literature emphasises the two-way nature of risk communication and the importance of taking account of public perception, understanding and response, including factors that influence perception of and response to communications, the role of individuals and community organisations as initiators of or contributors to risk communications is only recently being examined. Sutton (2009) identifies five key characteristics which differentiate social media from traditional ('legacy') communications systems:

- Collaborative
- Decentralized
- Lateral
- Networked
- Community driven

People are no longer dependent on hierarchical communications systems but communicate through their own networks, giving them greater access to information, more quickly and from more sources (op.cit.2009:10). Sutton makes the point that, *"Decentralized communication is not disorganized communication"* (ref.) and that as communications are shared, they get corrected and accuracy tends to increase. Not only do social media allow information to be communicated immediately to large numbers of people, it allows the process of information checking and testing of possible responses ('milling') to occur and potentially speeds up this process.

On the other hand, there are a number of concerns about the increase in communication of risk information through social media, from the possibility (a) that misinformation can become established and lead individuals to make mistaken responses[20], to (b) the lack of access to these media by significant sectors of the population, among them groups that tend to be vulnerable, such as the elderly or people with lower levels of achieved education (DFUSE Project, 2013, p. 8) Another issue raised in relation to HILP risks and space weather in particular is its dependence on communications networks that are themselves vulnerable to space weather impacts (Lee et al, 2012).

A recent report on 'City Evacuations: preparedness, warnings, actions and recovery' suggests that, *"The power of social media to compete with traditional media (e.g. television) during a period of crisis potentially has real consequences for how emergencies are managed"* (DFUSE Project, 2013:5). In a context of reduced trust in public authorities, the new communications technologies have created an information market place, where official communications have to

20. *'... groups of social media users could lead to the propagation of both intentional and unintentional rumours on internet platforms. These information flows may have significant implications as government policy and official communication is ignored with potentially serious consequences. In January 2010 a Twitter rumour led to the evacuation of Grand Central Station in Manhattan.'*

compete with information from other sources. This gives rise to challenges and opportunities for those responsible for managing risk. Table 3 summarises these risks and opportunities.

[Table 3. Summary of the opportunities and threats of social media for emergency planning – removed]

5.3 HOW DOES GOVERNMENT ENGAGE WITH THE PUBLIC ON HIGH IMPACT LOW PROBABILITY RISKS?

The literature shows that understanding of how individuals and communities become aware and make sense of risks has become more sophisticated over time, evolving from a one-way, top-down approach represented by the information deficit model, in which members of the public's lack of understanding of risk and subsequent failure to take action to reduce their risk was attributed to their "ignorance or stupidity" (Bennett, 1997:2). This model suggested that low levels of public understanding of risk could be remedied by increasing the amount of information directed towards them. This idea of providing "more and better information" is now seen as insufficient (O'Sullivan et al., 2012:2271) and this is reflected in UK government policy documents. The UK Department of Health guide on 'Communicating about risks to public health', for example, recognises this and notes that there has been a progression to approaches that allow a two-way process of communication between 'expert' and 'lay' perspectives (Bennett, 1997).

Space weather hazards are high impact low probability events, which are furthermore hard to predict (Krausmann, 2011). This uncertainty can complicate subsequent efforts to communicate the risks to members of the public. Extreme natural hazards like severe space weather events occur on timescales that transcend personal and organisational experience. The lack of personal experience of space weather or its impacts on the part of both policy- and decision-makers and members of the public creates a problem for communication because expert information about the risks has little resonance. Decision-makers may come to the conclusion that a severe space weather event is unlikely to occur on their watch, so they can leave to their successors. (National Academies, 2008).

The Science and Technology Committee (2012:1) notes that the Phillips inquiry into BSE highlighted the following lessons on uncertainty and the communication of risk:

- To establish credibility it is necessary to generate trust
- Trust can only be generated by openness
- Openness requires recognition of uncertainty, where it exists
- The importance of precautionary measures should not be played down on the grounds that the risk is unproved
- Scientific investigation of risk should be open and transparent
- The advice and the reasoning of advisory committees should be made public
- The trust that the public has in Chief Medical Officers (CMOs) is precious and should not be put at risk
- Any advice given by a CMO or advisory committee should be, and be seen to be, objective and independent of government

Uncertainty can also lead to difficulties in identifying and accepting evidence that challenges the existing status quo.

> *"Experts are also often reluctant to consider scenarios or risks which fall outside their 'comfort zones'. This can lead to the rejection of potential pointers or evidence simply because such indicators challenge current technical or scientific understanding, or lie outside normal situational awareness. This 'cognitive dissonance' is partly a cultural problem. People are often unwilling to give credence to improbable notions specifically because their professional or social community consider them too improbable."* (McFee, 2011:11).

Openness is probably the single most important factor in risk communication (Cabinet Office, 2003: 7). Greater openness can be achieved by recognising uncertainty where it exists; this openness can generate public trust (The Science and Technology Committee, 2012). Research has also shown trust to be multifaceted, with relevant factors including perceived competence, objectivity, fairness, consistency and goodwill (Bennett, 1997: 4).

Public trust is vital to establish credibility and can also be gained by assembling the available evidence and demonstrating that the organisation has an informed basis for their position (Risk and Regulation Advisory Council, 2009; McFee, 2011; The Science and Technology Committee, 2012). Organisations with high levels of public trust and credibility are important in communicating risk. Trust can also be lost again and there needs to be work in maintaining public trust by "being transparent about what is known and unknown; clearly distinguishing 'worst case scenarios' and what is expected; providing regular updates; and giving clear guidance as to suitable action for people to take" (McFee et al., 2011).

These features are "crucial" in how individuals assess the risk information and how they engage with it (Parker & Priest 2012: ref). In addition to seeking to gain public trust, organisations need to trust the public to respond rationally to openness (The Science and Technology Committee, 2012).

It is important to use the right vocabulary and language to explain risk when communicating to members of the public who may not be familiar with risk assessments. The Blackett Report (McFee, 2011 p.8) recommends: *"Government should work more closely with risk communication experts and behavioural scientists to develop both internal and external communication strategies".*

Box 4. Potential questions for the public dialogue

Potential questions for the public dialogue:

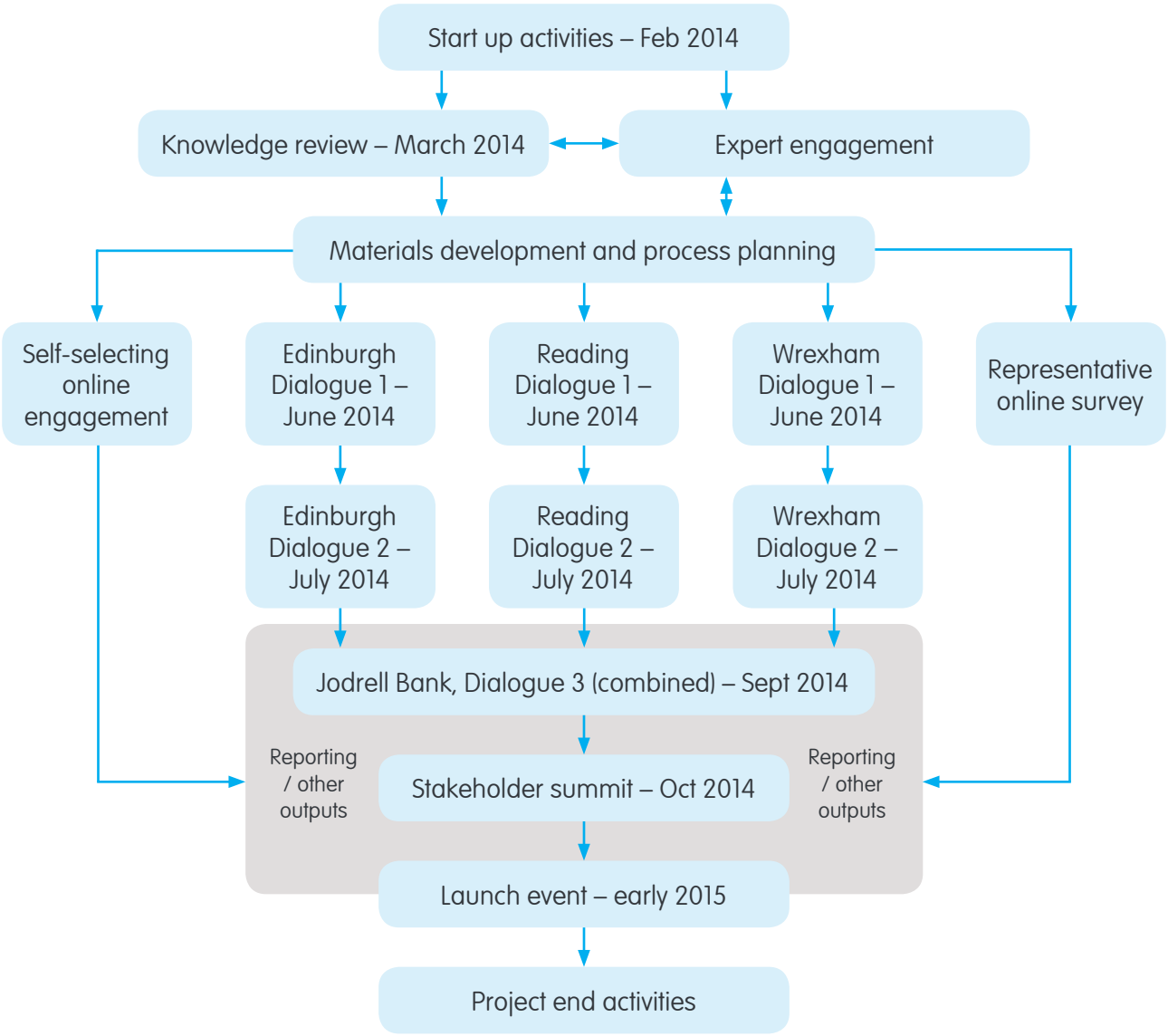
- Space weather forecasting: how interested are people in the science of space weather forecasting? What do members of the public see as the value to society of improving capacity to predict when space weather events will occur?
- What are the audiences for forecasts of space weather events? Is it important that regular information about the probability of space weather events should be communicated in a way that is accessible to the general public? What would members of the public want to know in order to understand the likelihood of a severe space weather event? What do people understand by the Carrington event having a 1 in 100 year return period?
- Space weather impacts / exposure: what space weather impacts are people most concerned about / can see having the greatest influence on their daily lives? How do people engage with the notion of the ripple / cascade effect from space weather? To what degree do people appreciate / understand the interrelated nature of space weather impacts? Does this matter?
- Space weather vulnerability: how vulnerable are different publics to space weather impacts, e.g. are some more susceptible due to the types of service they use / rely on? Is there any evidence of people taking action to reduce their susceptibility or increase their resilience to any space weather impacts? If so how?
- Space weather mitigation / adaptation: Willingness to pay for space weather risk mitigation measures for key services e.g. air travel / communications / satellite navigation systems.

Appendix 4
PROCESS OVERVIEW

Summary of activities

Below is a summary of the main strands of activity undertaken.

Figure 1 Process summary.



This interim dialogue report is designed to feed into the stakeholder summit and will be updated following the summit to form the final report.

Activities matched to outputs and objectives

The table below shows the various strands of work alongside the main products and outputs, matched to the relevant Sciencewise Guiding Principles. The guiding principles outline the essential elements of public dialogue on policy involving science and technology, namely: context, scope, delivery, impact and evaluation.

Figure 2 Activities mapped against outputs and Sciencewise Guiding Principles

Activity strand	Products and outputs	Relevant Sciencewise Guiding Principles*
1. Start up activities	• Agree project plan • Map products / outputs to recipient organisations	1. Context 2. Scope
2. Literature/knowledge review	• Scoping report • Context for dialogue materials	1. Context 2. Scope
3. Engagement of experts	• Input to dialogue materials • Development of key questions • Allocation of experts to dialogue events	2. Scope 3. Delivery
4. Development of content materials	• Public dialogue materials	3. Delivery
5. Dialogue elements	• Reports of findings • Participant contact details	3. Delivery 4. Impact
6. Reporting and other outputs	• Recommendations for communicating space weather • Insight into public response to risk and level of response (personal action / government spend) • Top line findings • Verbal presentation of findings • Overall project report	3. Delivery 4. Impact
7. Project end activity	• Framework for future engagement • Input to SW case study • Input to debrief meeting	4. Impact

*NB 5. Evaluation is relevant throughout the process.

Appendix 5
DETAILED METHODOLOGY

ACTIVITY 1: START UP PROCESS

The first task of the overall process was a start-up meeting, in which the project team met with STFC, Sciencewise, and evaluators to confirm the project plan, roles and responsibilities, and governance arrangements.

This was followed by an Oversight Group (OG) meeting on the same day to meet the project team, agree the scope of the knowledge review, and hear initial feedback from the OG on the proposed dialogue process.

ACTIVITY 2: KNOWLEDGE REVIEW

The purpose of the review was to gather, analyse and synthesise information about how people obtain, interrogate and make sense of information about space weather and similar risks, i.e. risks about which scientific knowledge is limited and which could potentially have far-reaching impacts on people's lives. The review provided a robust context and a starting point for designing the dialogue and developing dialogue materials.

To ensure a clear and useful focus, the scope of the review was discussed and agreed with the OG. The review included the following inputs:

- Expert interviews: given the broad range of relevant expertise of OG members, 30-minute telephone interviews were conducted with six members of the OG to explore the main issues relating space weather, the risks associated with extreme space weather events, the management of risks and public and stakeholder perceptions. Interviewees were also asked if there were any key perspectives missing from the list of interviewees or anyone else who should be contacted. Two stakeholders were mentioned by more than one interviewee and were contacted for more targeted information. The list of interviewees and the interview questions are shown in Appendices 1 and 2.
- Document review: both the interviewees and the wider OG were asked to provide relevant documents and materials for the knowledge review and for the preparation of materials for the dialogue events. A large number of reports, academic papers, media reports and grey literature were suggested. This source was further supplemented by Internet searches to fill in any gaps identified. Given the limited time available for the review, the team was guided in prioritising the review by the interviews and, in the case of the literature on risk perception, our own knowledge of the literature.
- Analysis and synthesis of the evidence: an analysis was made of interviewees' responses to each of the questions and key issues were drawn out. Key themes were also identified from the documents reviewed. The two strands of information were brought together and have been synthesised in the current report.

ACTIVITY 3: ENGAGEMENT OF EXPERTS / SPECIALISTS

Specialists were involved in the project in a number of roles, many of which overlapped:

- Members of the OG, providing guidance and accountability to the process.
- Information providers, supplying content for the dialogue materials on space weather and its impacts, as well as risk and mitigation.
- Dialogue participants, engaging in conversation with members of the public to learn about the specific questions, hopes and fears members of the public have about space weather and about public attitudes and responses to such risk.

- Reflectors, feeding back what they have heard, learned and taken away as a result of public input.

Discussion with the OG led to additional specialists being involved in the project, either as part of the OG, or as attendees at dialogue workshops to reflect specific views or expertise.

Following initial remote input to materials and completion of the draft knowledge review, there was a review panel meeting – a face-to-face meeting designed to:

- Complete the review of initial dialogue materials so that these could be finalised.
- Discuss the draft knowledge review.
- Discuss the roles of experts and stakeholders in the dialogue events.

ACTIVITY 4: DEVELOPMENT OF CONTENT MATERIALS

Building on the knowledge review and with further input from the OG and other specialists, the project team developed a suite of materials for use with the first round of public workshops and the website. Further materials were developed alongside the more detailed process planning for each subsequent workshop. See Appendix 9 for a full list of materials. The project team worked with a communications agency to develop a clear branding for the project, including a simple logo and style elements to apply across all dialogue materials to engender familiarity and consistency. This was also reflected in the project website and animation.

ACTIVITY 5: DIALOGUE ELEMENTS

The main element of the public dialogue was a series of recruited events with small groups of members of the public. Alongside this, two additional elements were carried out to learn about views from various members of the public in different ways – self-selecting online engagement via the website, and a representative online survey (i-omnibus).

Self-selecting online engagement. As part of the project website, there was an opportunity for anyone to input views. The group of people responding via this mechanism were completely self-selecting and thus likely to have an existing level of interest or knowledge about space weather – this is reflected in the responses received (see Appendix 5).

Representative online survey (i-omnibus). The Ipsos MORI i-omnibus process was used to undertake a representative survey of 1,010 members of the public. The aim was to gauge baseline levels of understanding and perceptions of space weather and related aspects of communication and resilience. See Appendix 6 for more detail.

Recruited dialogue groups. Three sets of public dialogue workshops were carried out, to reflect three different perspectives that would need to be considered in the event of an extreme space weather event: rural (Wrexham workshops), urban (Edinburgh workshops) and a national perspective (Reading workshops).

There were two events with the same group of approximately 20 people in each area, followed by a third workshop comprising a selection of participants from each location.

Workshop process in detail

Workshop 1 – building understanding. This first workshop focused on reactions and learning. During this day-long workshop participants were taken through a learning process in which they found out about space weather, its risks and potential impacts through a variety of materials and exercises. The idea of resilience and in relation to space weather was also introduced.

Experts were on hand to answer questions and interact as needed, in the spirit of being 'on tap, not on top' to ensure that members of the public were empowered from the outset and to enable a more level playing field later in the dialogue. At the end of the workshop participants noted what they had learned and what more they need to know, with the output from the first workshops feeding into the second set of workshops.

Between workshops 1 and 2. Participants were asked to undertake some homework between workshops. This involved talking to friends and family about the impacts of having no electricity or satnav as the result of a severe space weather event, as well optional activities such as trying to go for as long as possible without electricity. Participants were also encouraged to look at the project website and interact with the forum.

The project team compiled a Q&A document between workshops to answer some of the common questions arising in workshop 1. Input to some specific questions was sought from the OG, in order to feed back to participants in workshop 2.

Workshop 2 – responding to scenarios. Following the 4–5 week gap between workshops participants returned for a second workshop in the same three locations. To enable some more informal time for discussion and interaction between experts and citizens, the second workshops were held across a Friday evening and a shorter Saturday workshop – the aim was to add a depth to the relationships leading to increased mutual understanding and supporting the quality of dialogue to follow. The evening session involved hearing from participants about their homework tasks, and discussions with specialists about some of their organisational concerns and what they would find useful by way of input from members of the public.

The Saturday workshop involved reflections on the night before, followed by discussion of space weather scenarios – this included some participants putting themselves in the shoes of emergency responders, as well as discussion of national level impacts and mitigation in the event of an ongoing severe space weather events. The final session at these workshops involved discussion of some options for research, investment in systems resilience, and communication to increase levels of awareness and understanding around space weather. Participants discussed how they would divide up a fixed resource across the various options, as well as suggesting new options.

Between workshops 2 and 3. Outputs from the second set of workshops were analysed for specific ideas relating to research, systems or technological resilience, and communication to enhance awareness and understanding – these were then fed into the final public workshop.

Workshop 3 – testing ideas. A sub-selection of participants from each location (5–10 from each location) reconvened along with a larger group of experts. The emphasis of workshop three was on collaboration – working together to discuss the various options relating to research, systems or technological resilience, and communication.

Reporting. A combination of a flipchart record and laptop notes were used to capture discussions in each workshop. Audio recordings were used at tables to back up note taking.

ACTIVITY 6: REPORTING AND OTHER OUTPUTS

Stakeholder summit. Outputs from the three dialogue elements – the workshops, self-selecting online engagement, and i-omnibus – have been fed into this interim dialogue report to feed into the stakeholder summit. At this point, top line findings and a verbal presentation of findings will take place. The aim of the stakeholder summit is to share and build on outcomes. This event will draw together learning from all strands of engagement and encourage stakeholders to discuss who and how specific recommendations and messages would be taken forward.

Final report and reporting pack. Following the stakeholder summit, a final dialogue report will be produced, in both hard copy and electronic copy, and presented alongside all dialogue materials (including videos and graphics, and all of which will be suitable for use in other arenas), an executive summary, and any further recommendations for communications materials.

This reporting pack can then be handed to the relevant stakeholders, and the sections or topics of most relevance to each organisation will be signposted where this was discussed during the dialogue events or stakeholder summit.

Public participants who expressed a desire to stay in touch will be emailed a thank you note alongside a link to the final reporting pack. Those who displayed a high level of engagement could be approach to be involved in an ongoing sounding board, and will be put in touch with the relevant person at STFC.

Launch event / activity. Drawing together findings across all dialogue activities with responses from the stakeholder summit, there may be a small launch event, at which the dialogue report is presented to all key stakeholders.

Ongoing sounding board. Members of the public who have attended all three dialogue events and potentially the stakeholder summit will clearly have demonstrated a high level of engagement with the issues under discussion. These participants would be good candidates for an ongoing sounding board should one be desired – a group of members of the public with enhanced knowledge of space weather that could be reconvened to discuss the issues, responses, and communication around space weather with relevant bodies as required.

ACTIVITY 7: PROJECT END ACTIVITIES

At the end of the project there will be a wash-up meeting, provisionally focusing on learning and evaluation, identifying next steps, final actions, confirming how dialogue outputs will be disseminated, and to whom.

Appendix 6
DIALOGUE PARTICIPATION

The dates, locations, and number of attendees involved in each dialogue element are outlined in the table below.

Element	Date	Location	Members of public	Specialists	Observers
Edinburgh workshop 1	14th June 2014	Edinburgh	17	6	1
Reading Workshop 1	7th June 2014	Reading	19	4	2
Wrexham Workshop 1	28th June 2014	Wrexham	18	5	1
Edinburgh workshop 2	19th July 2014	Edinburgh	16	5	1
Reading Workshop 2	12th July 2014	Reading	16	7	3
Wrexham Workshop 2	26th July 2014	Wrexham	17	6	1
Combined workshop 3	13th September 2014	Jodrell Bank	18	10	1
Online engagement	June–October 2014	Online	71*	N/A	N/A
i-omnibus	26th–30th September	Online	1,010	N/A	N/A
Stakeholder summit	15th October 2015	Abingdon	5	22	1

*NB many of the members of the public taking part in the online survey identified themselves as having a degree of existing knowledge or interest in the topic of space weather.

Appendix 7
ONLINE ACTIVITY

Website overview

The space weather public dialogue website – talkspaceweather.com – was launched on Friday 6th June, to coincide with the first public workshop on 7th June. The website consists of five public pages and three password-accessible pages for participants.

The public pages are as follows:

- **Home** – a brief introduction to the project, a link to the animation, and links to other pages on the website.
- **Tell us your views** – a survey focusing on the potential impacts of space weather on everyday life, open to anyone to respond to.
- **The project** – an overview of the project, including a brief outline of process, as well as details on funders and delivery team.
- **Space weather** – information and materials on space weather, covering what space weather is, how space weather could affect us, the risk of a severe space weather event, and preparing for a severe space weather event.
- **Blog** – providing regular project updates.

The participant pages are as follows:

- **Home** – a reminder dates for the second round of workshops, a reminder of the homework task, biographies and photos of Oversight Group members, and links to useful materials.
- **The forum** – a message board to enable participants to ask questions and discuss specific issue.
- **Your profile** – an opportunity for participants to add a photo of themselves and other details.

Forum participation

Every participant, Oversight Group member and team member was provided with log-in details for the participant area of the website. Two topics were started by one of the team members in an effort to encourage participants to start responding. By the end of September, four participants had responded to these two posts, and no participants had started new posts.

Overall website traffic

Up to the end of September 2014, the site has been visited 1,209 times by 738 different people (61% new visitors), averaging 3.81 page views per visit.

The highest number of visits occurred just after the launch of the website, probably because the site was publicised on twitter via the public dialogue twitter feed as well as via a number of Oversight Group members. Other peaks often coincide with workshops and tweets.

For those website visitors for whom gender data was available, 46% of were female, and 54% male. Users for whom age data was available fell into the following categories:

- 18–24: 27.5%
- 25–34: 33.5%
- 35–44: 15.5%
- 45–54: 12.5%
- 55–64: 5.5%
- 65+: 5.5%

Approximately 55% of website visitors were identified as using US English, with 34% identified as GB English; the rest were identified as using a variety of other languages, including Dutch, French, Italian, Portuguese and Spanish.

Online survey responses

A total of 71 people responded to the online survey. The majority of respondents answered all of the multiple choice questions (Q1–8), with around 40% carrying on to respond to all of the text-based questions (Q9–18). The full set of responses by question is shown below.

A number of respondents indicated they had an existing level of knowledge or interest in the topic of space weather. This should be taken into account when reading their input.

Question 1. Are you a resident in the UK / outside the UK?

Response	Number	Percentage
In the UK	55	77.5%
Outside the UK	16	22.5%
TOTAL	**71**	**100%**

Question 2. How old are you?

Response	Number	Percentage
Under 18	2	2.8%
18–24	6	8.5%
25–34	16	22.5%
35–44	10	14.1%
45–54	14	19.7%
55–64	15	21.1%
65–74	7	9.9%
75 and over	1	1.4%
TOTAL	**71**	**100%**

Question 3. Are you male or female?

Response	Number	Percentage
Male	38	53.5%
Female	27	38.0%
Prefer not to say	6	8.5%
TOTAL	**71**	**100%**

Question 4. How much would you say you know about what space weather is?

Response	Number	Percentage
Nothing	2	3.0%
Not much	7	10.6%
Not sure	1	1.5%
A little	25	37.9%
A lot	31	47.0%
TOTAL	**66**	**100%**

- Comments from those saying "nothing": no comments
- Comments from those saying "not much": no comments
- Comments from those saying "not sure":
  - Terrible construction of the question.
- Comments from those saying "a little":
  - I have been studying space weather in general since 2012, when I discovered Earth's poles shift approx every 3600 years.
  - Space weather is how weather in space effects our instruments and well being on earth
- Comments from those saying "a lot":
  - Amateur astronomer. Professional chemist. Have attended lectures about space weather and the threats from it.
  - I work in emergency response to radiation
  - I have an MSc in Astronomy and Astrophysics.
  - Currently undertaking an MSc research project on Space Weather & Risk Perception, Risk Communication of this 'new' threat in the UK
  - I am a postdoc actively researching the ionosphere
  - Former deputy director of Kielder Observatory, and science writer for ESA
  - PhD student in space weather instrumentation
  - I have a PhD in magnetospheric physics.
  - I'm aware of plasma cosmology which successfully explains the Sun's environment in electrical terms.

Question 5. How much would you say you know about the possible impacts of space weather?

Response	Number	Percentage
Nothing	3	4.8%
Not much	4	6.3%
Not sure	2	3.2%
A little	23	36.5%
A lot	31	49.2%
TOTAL	**63**	**100%**

- Comments from those saying "nothing": no comments
- Comments from those saying "not much": no comments
- Comments from those saying "not sure":
  - Question construction still terrible.
- Comments from those saying "a little":
  - Again, pole shift related research.
  - Increases in radiation dose in flight Induced currents in power facilities.
- Comments from those saying "a lot":
  - As for Q5. Have taken some limited interest in ways to increase resilience. e.g. installation of wood burning stove.
  - Well, not as much as an engineer, but enough to sell my research as important.
  - However, despite a PhD in magnetospheric physics, I wonder what the impact 'on the ground' to the average person would realistically be.

Question 6. How worried are you that a severe space weather event might impact you personally?

Response	Number	Percentage
Not at all worried	7	11.1%
Not very worried	21	33.3%
Not sure	3	4.8%
A little worried	25	39.7%
Very worried	7	11.1%
TOTAL	**63**	**100%**

- Comments from those saying "not at all worried":
  - Pareto Distribution of geophysical phenomena.
  - We need to understand the basis of our fears before we can learn to deal with them and stop worrying unnecessarily.
- Comments from those saying "not very worried":
  - Given there frequency, compared to other risks.
  - I consider it a fairly low risk against the larger list of "things to prepare for".
  - I don't know enough about it to be worried. It feels like something beyond my control.
  - I grew up regularly dealing with power outages and live in a mild enough climate and small enough town to handle a long loss of services.
- Comments from those saying "not sure":
  - I am not a worrier. A space weather event might affect my life, though it would be temporary and effects would be reversible. I do not see it as a threat to my life personally – I am not part of a vulnerable group (eg., elderly, disabled, ...). Any threat to my personal finances will be insured (bank errors due to electronic problems) and I do not have a larger interest (eg., company owner, board chair, ...)
- Comments from those saying "a little worried":
  - Worried is the wrong word.
  - The lack of focus/effort and mitigation in real terms from Govt's in to this problem is what worries me.
  - Comments from those saying "very worried": no comments

Question 7. How worried are you that a severe space weather event might impact your community?

Response	Number	Percentage
Not at all worried	4	6.5%
Not very worried	23	37.1%
Not sure	4	6.5%
A little worried	22	35.5%
Very worried	9	14.5%
TOTAL	**62**	**100%**

- Comments from those saying "not at all worried":
  - Pareto distribution of geophysical phenomena.
- Comments from those saying "not very worried":
  - As for previous question.
- Comments from those saying "not sure":
  - What does 'my community' consist of?
- Comments from those saying "a little worried":
  - I would guess that most people don't "prepare" for anything and have no plan in the event of power outage (e.g.)
  - I may affect services such the emergency services and power grids. This may cause serious problems if there are no mitigations: eg., back up power in hospitals for life-support.
- Comments from those saying "very worried":
  - Everyone will be affected.

Question 8. Which of these impacts would you be worried about (if any)? Tick as many as you like.

Response	Number	Percentage
Satellites	35	59.3%
Electricity	48	81.4%
Communications	44	74.6%
Aviation	23	39.0%
Transport	24	40.7%
None of these	2	3.4%
TOTAL	**59**	**N/A**

Comments:

- atm banking get there time from GIS satellites if they go down so does the banking system. If zone subs 33 to 11 are damaged as in Canada no replacement transformers because of cost (re satellites and electricity).
- These three are really important in our daily lives although aviation and satellites for TV and GPS are not that important in daily use. Without electricity, we would not be able to live a day well and communications such as phone and whatsapp are important too... Long distance travels by road have become part of daily routine which is why transport is important too... (re electricity, communications, and transport).
- Most man-made creations will be destroyed (no impacts selected).
- Grid-Down effects all others (re electricity).
- All possible effects, which need to be catered for (re all impacts).
- All these could be affected by a solar storm (re all impacts).
- my home runs on electricity and i like to stay in contact with my family through communications (re electricity and communications).
- the failure of electronic modules within the equipment (re all impacts).
- u have a young baby so would need electricity to make her hot bottles and prepare her hot meals (re satellites and electricity).
- I can cope without most of these for several days. Communications – as to what is happening in the wider area would be useful (re communications).
- The above are essentials we use day to day of our lives (re satellites, electricity, communications, and transport).
- Too heavily reliant on these things such as electricity and communications, a major impact on the entire first world population (re electricity, communications, aviation, and transport).
- These things would impact my work and daily life (satellites, electricity, and communications).
- While our lives would be significantly impacted for a short period of time, our ability to function (albeit in a reversionary mode) would continue assuming electricity supply continues. Without electricity life becomes very much less easy.
- because it will effect my day to day life

Comments from those saying "none of these":

- My life(style) is only slightly dependent on electricity.
- Why worry about something you can't do anything about?

Question 9. What action would you personally take before, during and after the event?

- Have radiation blankets in survival kit supplies to survive for at least a week in NZ if we lost the National Grid could be months If power lost in America for more than two weeks we could have 109 Fukishima melt downs.
- Watch the natural phenomena, the aurora, the meteors.
- Buy staple food and fuel for the car, batteries and candles; back up computers; find list of emergency services telephone numbers; check basic landline telephone (non-mains powered).
- Generally I would make people close to me aware about the disaster, what should be done and what not (if I know by then).
- Before: Shelter in place. During: Hang on! After: Assist survivors, build shelters, create safe water supplies and start farming.
- Preparation along the lines of Beans, Bullets and band aids.
- Shut off power.
- None.
- I would be wary of flying if there were an extreme event.
- That really depends on the nature of the event! Firstly I would consult whatever media was available (online first) to

see how big the even was and what its likely impact would be. If any of those impacts were on any part of my daily life, I would of course take steps to avoid problems. But it really depends how bad the impact is – could be anything from no GPS signal (not a problem) to total failure of the rail network and local blackouts.

- Look at the Space Weather alerts at NOAA.
- Try to contact family member to make sure the are safe and have everything that they need.
- I would get food and water in, candles and blankets to keep warm, and try to make sure my family were ok.
- Turn off all possible appliances and disconnect them from the mains. Ensure stocks of water. Keep indoors during. Wait for further information after.
- Before: Prepare a grab bag with enough essentials for 4 days During: Try to find alternative ways of doing things that were affected After: Try to reduce my reliance on such things that were impacted.
- Have some tinned food stored. Torches are to hand.
- Very little beforehand – more likely to take action after once you know what the implications might be.
- Get in touch with friends (especially those living relatively close to me) and neighbours.
- Before – have some food and water for a few days During and after – check neighbours, find out what's going on and how long it'll last.
- Ensure that my emergency supplies are up-to-date beforehand, nothing special during (but make sure to do nothing dangerous that would divert emergency services), and get back to normal as soon as possible.
- Unplug the TV and computer and wear a Tin Hat.
- Back up data perhaps...
- Wish to understand its effect and action I may take.
- Before: Take part in debates on space-weather-proofing (SW-proofing) society. During: Enjoy the aurora which would be visible from the UK in the case of an extreme event. After: Check family and friends have not been affected. Check communications, check plans for flying, check banking.
- Switch off all electrical equipment, and watch the daytime aurora.
- Before: Stock torch/radio batteries; Isolate electronic devices; Stock lamp oil; Charge mobile devices; Replace cordless phone with plug-in phone; Obtain cash for emergencies.
- Charge mobile phone, but torch batteries, buy canned food that can be eaten cold, encourage friends and family to take precautions.
- I would try to find out more information about what the likely impact would be and avoid unnecessary travel. Would also try to talk to neighbours, friends and family about their awareness and likely movements, especially the elderly with limited mobility.
- Would generally unplug everything that could be impacted, although not take EMP precautions. We can live without electricity and running water for a period of time, so life would not come to a grinding halt.
- Personally before an event i would put my electronics in a lead box. During i would watch the Northern Lights and after i would try and stock up.

Question 10. What would you need to help you cope?

- Warning IPS Australia does a good job.
- Lots of ammunition to calm my possibly hysterical neighbours.
- Information on radio and tv as well as internet.
- Pamphlets and a society notice and communication before the event takes place.
- Food, water and medical supplies. Also would need my young adult children to be in a safe location, or preferably our family together.
- Communication.
- Information.
- Information.
- Information.
- Good information on practical impacts.
- More information.
- More information and planning.
- Family support.
- Information on the impact in the wider (say within 30 miles) area.
- More information about the possible effects of space weather.
- Up to date information about what is happening and when normal service will resume.

- Difficult to know – if TV/electronics are down there is little you will be able to find out. Information in advance (e.g. a warning) would at least let us know what is happening and why.
- Good, unbiased, practical information.
- Nothing.
- Water supply, food, source of heat, back up prescription medication.
- A Tin Hat.
- We coped for millennia before we had satellites/power etc.
- Reliable, unambiguous, coordinated information.
- It is important that potentially affected services can report on effectively on their status in respect to space weather. For example, airlines should be aware that space weather could affect them, and report on the status of their service if extreme space weather were to occur.
- My wife.
- News updates; Cash; Heat; Light.
- Information, but not government spin, don't dumb down the science.
- An alternative to mobile phone, access to transport to ensure family members are safe and secure, and access to work. Alternative source of power, if interrupted.
- Nothing.
- Government assistance to keep the country stabile with food and water supplies

Question 11. What action do you think your community would need to take before, during and after the event?

- Close electrical system down and earth out equipment better to lose power for two days than months.
- None.
- Care of the vulnerable if food, water, power supplies interrupted.
- Be prepared before hand like with power cuts that we would experience, communication less society etc.
- Communities in unfavourable geographies (coastal, volcanic, close to nuclear facilities) could relocate their populations to higher elevations or otherwise safer locations.
- Inform locals what they should do to be ready.
- Stock up on supplies.
- None.
- Prepare for major effects on, for example, the electricity grid. Get response plans in place for all possible effects.
- Affected industries would need to have contingency plans in place. General public would need to listen to expert advice during the event.
- Be more aware of the possible event.
- There would need to be good communication and a point of contact.
- Help each other.
- Ensure stocks of food, water, fuel are available without recourse to electricity.
- Communicate with vulnerable population.
- A severe space weather team is set up with defined role. A help/information point is identified in the local area.
- My community is quite used to dealing with e.g. power cuts, and we tend to pull together. Main concerns would be shops running out of food, and loss of income.
- Keep in touch. Determine ways of helping and supporting each other.
- Not much, as I think the risk is slight.
- Ensure that back-up generators are in place and enough petrol is stored to access people in need of medical attention. During, it would be nice if people didn't panic.
- See Above.
- If we're talking a CME/Carrington type event, not much, if we're talking a meteorite strike, then food stockpiling would I suspect e useful.
- Rely upon and act on 10 above.
- Before: SW-proofing of hospitals and other essential services. During: Recognising and being diligent to the risks during space-weather events. There may be power cuts or communication failures. Flying may perhaps be risky (depending on the reliance of aircraft on space-based assets). After: Find what has been affected.
- See previous response regarding 'my community'.
- Central meeting point for mutual support. Knowledge of vulnerable residents. Ideally a pre planned Community Resilience Plan.

- I think fire safety would be key as likely people would use candles.
- Securing power supplies, communicating the potential risks and advice to residents about any likely risk to their health and security.
- Before; filling baths with water, getting in tinned food, candles, unplugging potentially affected devices. During; sit tight After; check impact on all equipment.
- Stock up on previsions. during not really sure and after make sure people are looked after and the flow resources are secure.

Question 12. What would your community need to help it cope?

- Civil Defence needs to have in place some communication operating after back up generators run out of fuel after 2–3 days.
- Time.
- Information; back-up plans for emergency services, power cuts, control of panic buying.
- Absolutely nothing. We would be prepared to live like in the 1800s maybe. So it would not require anything rather would require the removal of things.
- A closer medical facility.
- Communicate.
- Plenty of water and food.
- Information and communication plans.
- Mainly information during an event. Government should handle the main issues and inform the public.
- Good information.
- More information from central government in preparing for this event.
- Have a plan in place for such an event happening.
- Help from government.
- Unsure. I'm not totally familiar with local government preparation plans.
- A special 'Community Emergency Group' to help with the coordination of such activities.
- A system to check on the older people in the area. Up to date information about what is happening and when normal service will resume.
- Fairly self-reliant – would not expect or anticipate help from outside sources.
- Good, unbiased, practical information Willingness to work together.
- Not sure, just moved here.
- See above.
- As for Q11.
- Resources if required.
- Information on what space weather is, how to identify it (ie., strong aurora, power cuts, etc.) and what to do if it occurs (ie., where to find information, what activities to be wary of). A reporting system that is space-weather-proof would be useful. If TV is disrupted for some, then radio should be used (local stations should be least affected). There may be public places where information can be displayed (airports, train stations, ...). In a lot of cases the public do not need to know the effect of SW on a system, as long as the system is not dangerously affected. If a train can run during periods of large electrical disturbance, as there are plenty of safety protocol in place, then the public need only recognise a electrical problem, rather than space weather problem. A public aware that space weather may affect signalling on trains, though is reassured that the system is SW-proof to the level that it is not a danger to them, is safe. If the effect was better defined (ie., predictable) then the public could be informed of disruption prior to electrical problems, and delays, and take an alternative action.
- Likewise.
- Information; Reassurance.
- Information.
- Alternative power supplies, secure links to transport systems that may be interrupted.
- Potentially supplies of generators for the sick to run essential medical equipment.
- Aid by government or Red cross.

Question 13. What action do you think government (local or national) would need to take before, during and after the event?

- During storm intensity close national grid down and earth equipment if need be communicate with distribution companies to do the same.
- Resign.
- Information to people and companies; Back-up plans in case GPS is disabled for any length of time; strategic thinking about risk to power network and potential long-term interruption of power supplies.
- They should assure the people that after the event, everything would be back to normal.
- Before: Inform populations in unsafe areas that they need to relocate. There won't be much government assistance afterward. Most places will be devastated.
- Control the riots.
- Fund research.
- Planning and developing information communications.
- Identify areas of the infrastructure that may be vulnerable. Make it more robust where possible and plan to mitigate effects during an event.
- See above. Really depends on the nature of the event and its expected impacts! Contingency plans and realistic models will be necessary beforehand.
- Again this needs to be raised more so making the public more aware of this event.
- As above.
- Store food, water, have emergency services ready to help.
- Unsure. I'm not totally familiar with regional government preparation plans.
- Provide information to people in a number of different formats especially to the vulnerable.
- Make sure there is a communication plan in place to keep the public informed about what is happening and when normal service will resume.
- Information in advance if possible would be helpful – I would imagine resources would be focused on the elderly/ vulnerable and emergency services rather than the general population. People need to look out for themselves and not be so reliant on government.
- Clear information to all. Develop resilience plans. Make and implement decisions which may be unpopular in the short term but which will enable the country to better cope with such events.
- Some thought and planning into effective response.
- Before it would be helpful to upgrade the national grid.
- Run around like headless chickens.
- Invest some money in it!
- Provide leadership – not chaos.
- Before: Have a SW-proofing strategy. Liaise with private companies on their intended SW-proofing strategy. During: Monitor the progress of the event. Report on impact and status of potentially affected systems. After: Report on impact and status of potentially affected systems.
- Provide everybody with tin-foil hats.
- Awareness raising; 'Local' Community Resilience Planning; Communications/News Service.
- Provide the public with information (and suggestions) to allow them to prepare (this doesn't have to be reassurance if it's not a reassuring message).
- Advice to communities, interaction with other governments to ensure a co-ordinated effort to tackle risks to transport links.
- I think that public service broadcasts need to be prepared explaining how to protect yourself and those around you. Warn essential services and put uniformed services on stand-by for public duties. Put in place back-up plans for food, water and money.
- Before Shut off all power systems disconnect everything from grid and have back up transformers and power supply. During: Not Sure and After make sure the country is stable.

Question 14. What do you think government (local or national) would need to help them cope?

- Early warning and world wide communication as storm intensifies Argentina or Chile could early warn NZ due to planet rotation UK same with Russia and EU and vice versa.
- Time.
- Reliable scientific information, including forecasts and risks.
- Communication media before the event.

- On a national level, the plans are already in place. I'm sure those underground bunkers and millions of rounds of ammo will help them cope just fine.
- No idea.
- Information and plans.
- Better forecasting, and data flow during an event.
- Advice from scientific experts. Monitoring information from space probes.
- As above.
- Emergency planning.
- Members of the community to step in.
- A more personally prepared population :)
- More communities that are resilient.
- Research into how these effects are likely to impact the country.
- Resources..... But I imagine there are greater priorities.
- Champions within communities. Excellent communication strategies.
- Understand the science and impacts.
- More educated leadership.
- A Tin Hat.
- Solid advice to circumvent the trash which the like of the Daily Mail will doubtless publish.
- A central, reliable, source of information that has the trust of the majority of the population – no longer the prime minister or BBC, perhaps Channel 4.
- Government needs to be well informed from the scientific side (the facts about SW) and from the industry side (the vulnerability of aircraft, hospitals, power grids,...). It needs to be well understood what monitoring and reporting will work. Perhaps some legal requirement would need to be in place to bring companies into line for safety and service status reporting, in regard to SW.
- A large supply of tin-foil.
- Effective communications.
- A miracle.
- Reliable access to detailed information about the risk, and how it was proceeding and the likely impact. Alternative sources of power and communication to allow vital services to continue to be offered.
- Planning?
- Back up resources.

Question 15. What action do you think companies (local or national) would need to take before, during and after the event?

- Varies with intensity of storm should have some manual procedures in place to operate with no electricity possible public chaos panic with no electricity.
- Resign.
- Planning ahead of time, responsiveness during, e.g. to staff unable to travel, including if schools are closed, resilience in the face of no Internet access. Information to customers.
- Be prepared to complete all electronic work before the black out and do other mechanical works during the black out.
- Inform their employees that it's time to go home to their families and consider their locations and loved ones. Then close up shop.
- Have backup electrical supplies.
- Airlines would need contingency plans for staff Power nets may have enough obsolescence, but still need to plan.
- Companies should be prepared for power outages, however unlikely.
- See above. Contingency planning.
- As above.
- Unsure how much we can do for something we are unsure of.
- Prepare, and help one another.
- Communicate important information to its customers.
- Strategies that they should already have in place for power cuts and communications breakdowns.
- Not sure – you can only prepare for so much.
- Risk assessment. Clear plans for coping.
- Build in some resilience and redundancy to systems.

- Recent plans for breakdowns of central services, clean-up plans for hazardous material sites.
- Harden electronics systems, install surge protection on electrical systems. Have offline systems to cope with serious temporary disruption.
- Space agencies with satellites i orbit would need to consider a strategy.
- Act to protect their products, services and customers.
- Before: Companies should think about how their service might be affected by space weather: Would their service be dangerously affected by disturbance (eg., is train signalling SW-proof?). What is the mitigation of potential problems? Are employees aware that there may be SW problems? Can employees report to the public on the outcomes, if need be? During: This depends on their service and mitigation plans. They should think safety first and then also about report disruption to services to customers. This should be as honest as possible, and therefore as well informed as possible. After: Reporting on the services. Relay of disruption information to government and engineering/science communities to better understand future potential disruptions.
- They should follow government directives.
- Address as a specific business risk in organisations Business Continuity Plans.
- Try to reduce the risk. But have a plan for how to cope with the consequences – not a space weather plan, just how to cope with no power, comms etc.
- Preparation and planning for alternative locations, and perhaps means of communication in the event that power and telephone contact is interrupted. A challenge in the context of electrical and internet dependence.
- Review their DR plan to determine whether there is a "non-connected" alternative method of working.
- Before: Power supplies and electronics During: Not Sure After: emergency money and aid.

Question 16. What do you think companies would need to help them cope?

- Early warning good communication Civil defence through local and central government.
- Time.
- Information about what to expect, timings of any interruptions to services such as long-term power cuts.
- Extra-time work by the employees.
- Information. You guys can really help with that.
- Zero.
- Information.
- Information mainly.
- See above.
- As above.
- Have a emergency plan in place.
- Support of employees.
- A Business Continuity Plan.
- Up to date information about what is happening and when normal service will resume.
- Not sure. If electronics and Internet are down many companies would not be able to operate. Good contingency planning/recovery measures would help.
- Buy in from employees Guidance from government.
- No idea.
- Advice on the problem, good advance warning of events and a tin hat!
- Communications infrastructure would need to be backed up/or made more robust.
- Preparation.
- Advice from experts on the potential effects during SW phenomena. A good reporting stream to advise on potential events (ie., forecasting).
- Lower interest rates.
- Business Continuity Plans; Agile working arrangements; Robust IT back-up/data retrieval systems.
- Forecast information, warning time to safely shut systems down.
- Alternative power supplies, and contingency plans for the continuation of certain operations to continue in the event that a single system is interrupted.
- Access to a risk assessment.
- Money.

Question 17. Of all the things you've discussed in questions 9–16, what would you prioritise?

- Early warning One point to make decision to close electrical grid down and earth out no questions asked not political stand alone decision made on good and varied accumulated information received.
- Calm, patience.
- Information – form scientists in forms useful to government, industry and people – and from government and industry.
- Foremost, the government assurance is required by the people and then probably the completion of work at companies and lastly preparation by the community for the black-out.
- Sending military members home to their families, which would involve a lot of air travel and we need to allow enough time to get the soldiers home, as well as the general populations to their destinations, before the grid goes down.
- Communications.
- Communications planning.
- Protecting the infrastructure.
- Good information from scientific experts, properly disseminated through the media. Accurate monitoring of space conditions and realistic models so impacts may be predicted.
- As above.
- Food and warmth.
- Q9 what i could do.
- Depending on the season – Shelter, Water, Fuel for heating/cooking, food supply.
- Prioritise up to date information to the public.
- Communications plan during an severe space weather event.
- Support for vulnerable people and emergency services. People should be more resilient on an individual level – in our community we often have power cuts/loss of Internet, and we cope. Stocks of food, keeping your petrol tank topped up etc. should help. Concerns would be lack of food in shops as seen during the petrol blockades.
- Combination of government decisions and guidance and community support systems.
- Redundancy in systems.
- 15, 13, 11.
- The Tin Hat.
- Govt investment.
- A widely accepted reliable means of communication.
- Companies are the most important part of this, as they are the agent providing potentially affected services to the public. Even if the public do not know about space weather, companies should have an obligation to keep them safe.
- My wife.
- Communications.
- Information to the public on space weather and likely consequences (it needs to be accessible but engaging – get Brian Cox to present it!).
- Own arrangements at home and with family.
- Public service broadcasts and risk assessments.
- Make sure power systems and transformers are kept in reserve.

Question 18. Do you have any more comments?

- We have a society completely dependant on electricity a 1859 Carrington event to day hitting America could cause the end of life on this planet due to public chaos and nuclear meltdown we need a good back up of replacement transformers Govt assistance for companies to carry the stock 33kv to 11kv about 1.5 million each NZ dollars.
- My life(style) is little dependent on infrastructure. I live in the middle of the largest body of potable water, and in a rural and isolated community that still can be independent of the outside world. Hysterical fear of catastrophe is ignorant of reality. If it was likely to happen, then it would have already happened.
- More science training for government and administration.
- This survey is intriguing. For everyone's sake, please draw the conclusion that providing people with vital information is professionally and ethically incumbent upon scientists. We count on you for your expertise. Each person can then make their own informed decision. You will do humanity the greatest service, and you know it. We know it too. Thank you and good luck with this.
- No.
- This consultation seems rather unsure of itself. Lots of things that 'could' or 'might' happen – it's hard to say what we would do without a specific hypothetical scenario. Are there any statistics for how likely/frequent such events are?

- Unless more is done (& quicker) in raising the profile risk & communicating this risk. Then the risk perception will remain low and all the questions above will be relevant.
- I've never really thought about this, there are things i can do to prepare.
- No.
- There is only so much the government can do – we can't prepare for everything. People and communities need to do more to look out for themselves than relying on the state to look after them. Perhaps a few days without electricity and mobile phones would do us all the world of good.
- Perhaps Valve radios would be useful for when all the unprotected electronic stuff is fried!
- The threat is real, yet gets hardly any attention. This must change.
- Don't create anxiety to raise your project up the agenda.
- No.
- We miss the old 'Petunia' Gov Information Films. Effectivity of Emergency Planning arrangements is variable in UK and duty to Warn and Inform is weakest of all. Needs improvement.
- Why is the government taking this so seriously *now*? Is there something likely to happen?

Appendix 8
I-OMNIBUS

The i-omnibus took place between 26th and 30th September 2014, and involved 1,010 people representative of adults aged 16–75 in the United Kingdom.

Below is a summary of demographic data followed by a summary of responses.

DEMOGRAPHICS

Demographic label	Category	Number (absolute)	Number weighted to reflect nationally representative poll
Gender	Male	500	500
	Female	510	510
Age	16–24	159	161
	25–34	180	180
	35–44	184	185
	45–54	189	188
	55–75	298	295
Social grade	AB	255	267
	C1	282	282
	C2	230	224
	DE	243	237
Education	GCSE / O Level / NVQ12	272	255
	A Level or equivalent	192	192
	Degree / Masters / PhD	454	479
	No formal qualifications	92	84
Presence of children (17 or under)	At least one child present	252	236
	No children present	758	774
Region	North East	44	44
	North West	117	117
	Yorkshire and Humberside	94	91
	West Midlands	89	92
	East Midlands	76	77
	East of England	93	94
	South West	90	88
	South East	138	136
	Greater London	133	134
	Wales	51	50
	Scotland	85	86
Area	Urban	818	817
	Rural	190	190

Question 1. How much, if anything, would you say you know about space weather?

Response	Number	Percentage
A great deal	11	1%
A fair amount	53	5%
Just a little	153	15%
Heard of it, but know almost nothing about it	289	29%
Have never heard of it	469	46%
Don't know	36	4%

Question 2. Which, if any, of the following have you heard of?

Response	Number	Percentage
Northern lights	932	92%
Aurora borealis	756	75%
Solar flare	710	70%
Solar wind	585	58%
Solar radiation storm	384	38%
Geomagnetic storm	332	33%
Coronal mass ejection	177	17%
None of these	39	4%
Heard of any	971	96%
Heard of 2	136	13%
Heard of 3	177	18%
Heard of 4–5	317	31%
Heard of 6–7	241	24%

Question 3. Would you be more or less concerned if you heard that a power cut in your area was caused by space weather than if you heard it was caused by a storm?

Response	Number	Percentage
Much less concerned about a power cut caused by space weather	30	3%
Slightly less concerned about a power cut caused by space weather	51	5%
About the same	448	44%
Slightly more concerned about a power cut caused by space weather	227	23%
Much more concerned about a power cut caused by space weather	111	11%
Don't know	143	14%

Question 4. For dealing with emergencies and disruptions such as power cuts, it is recommended that households routinely keep items such as the following in their homes: a torch, spare batteries, candles/matches, tinned food, bottled water, spare medication, a battery-powered or wind-up radio, a list of contact details for friends/family/ doctor and so on. Which of the following statements best describes how you would feel about unexpected power cuts which were to last the following length of time?

Response	4 hours		12 hours		24 hours		2 days		4 days	
	No.	%	No.	%	No.	%	No.	%	No.	%
I have adequate preparations in place for a power cut of this length and I would be able to cope with the likely disruption	660	65%	412	41%	262	26%	118	12%	95	9%
I have adequate preparations in place for a power cut of this length but I would struggle to cope with the likely disruption	94	9%	254	25%	230	23%	196	19%	140	14%
I have little or no preparations in place for a power cut of this length but I would be able to cope with the likely disruption	118	12%	154	15%	236	23%	205	20%	166	16%
I have little or no preparations in place for a power cut of this length and I would struggle to cope with the likely disruption	48	5%	95	9%	178	18%	377	37%	482	48%
Don't know	90	9%	94	9%	105	10%	113	11%	127	13%

Question 5. Space weather is a term used to describe conditions in space, near the earth. It happens all the time at a level we might not notice here on Earth, but sometimes it can cause power cuts or other disruption to our communications, electricity, satellite, and transport networks. Based on the information above, which of the following do you MOST want to find out more about?

Response	Number	Percentage
The possible impacts of space weather	451	45%
What you can do personally to prepare for the possible effects of space weather	331	33%
What causes space weather / types of space weather	285	28%
What others such as government and industry are doing to prepare for the possible effects of space weather	248	25%
Something else [please specify]	16	2%
Don't know	173	17%

Question 6. Where would you look to find out more about space weather?

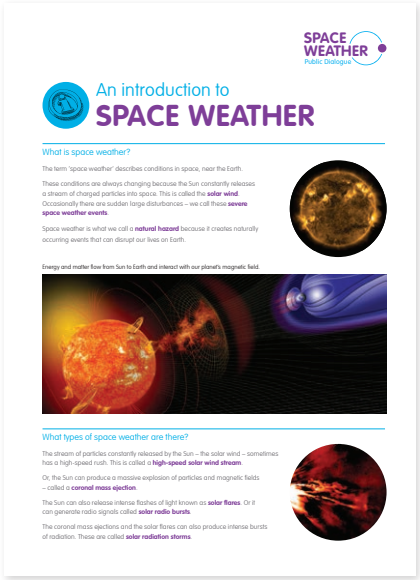
Response	Number	Percentage
Search engine	592	59%
Met Office website	321	32%
Television	225	22%
Scientific journals	189	19%
Online newspapers or news websites	183	18%
Weather forecast	149	15%
National newspapers	77	8%
Radio	57	6%
Conversations with friends and family	55	6%
Social media	44	4%
Local information points such as town hall, library	30	3%
Blogs	19	2%
Conversations with work colleagues	18	2%
Local newspapers	13	1%
Other (please specify)	17	2%
Don't know	58	6%
None of these	20	2%

Appendix 9
DIALOGUE MATERIALS

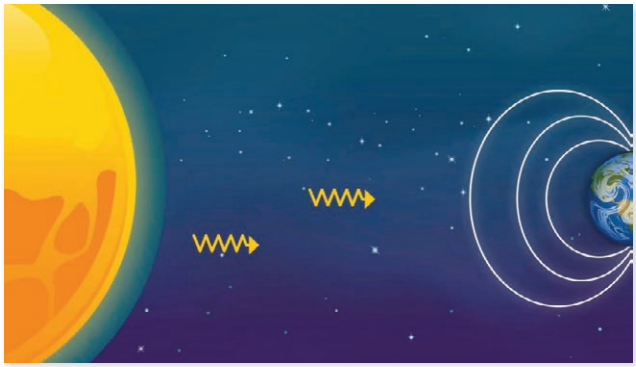
Here are some examples of the materials used in the public dialogue, followed by a full list of all materials developed for use in the public dialogue. The animation and a selection of other materials can be found at talkspaceweather.com

Public and participant-only home pages

Information sheets



Stills from the space weather animation



Process stage	Title	Description
Whole project	talkspaceweather.com	Public website
	Participant forum	Password protected website
	Online survey	Online survey via website
	Posters	A range of posters covering
	Space weather animation	Short animation outlining basic information on space weather, its impacts, and some key questions covered by the public dialogue
Workshop 1	Presentation	PowerPoint slides covering the whole day's activities, including specific presentations on what space weather is, it's impacts, risk, and resilience
	Impact cartoons	Cartoon conversations with blank boxes for participants to fill in, illustrating imaginary conversations about specific space weather impacts
	Impact worksheets	Worksheets asking participants to consider the effects of satellite, electricity, communications, aviation and transport impacts on them, their communities, and wider society
	Space weather information sheets	Double sided information sheets covering an "introduction to space weather", "impacts of space weather", and "risk and space weather"
	Quiz	Short quiz with four questions covering information already
	Action sheets	Worksheets asking participants to consider actions responsibilities and help required before, during or after a severe space weather events, from four perspectives: personal, community, government, companies
	Review	Worksheet asking participants to list things they have learnt at the end of workshop 1, in relation to: what space weather is, impacts, risk, and resilience
	Take home postcard	Postcard outlining a homework task for participants to undertake in between workshops
	End of workshop information sheet	Take home letter, including information on what happens next and guidance on using the website
Workshop 2	Presentation	PowerPoint slides covering the Saturday activities
	Talking head film clips	Film clips of Dr Lucie Greene talking about various aspects of space weather and its effects on Earth in more detail
	Space weather bingo	Bingo cards all containing the same words and phrases related to space weather but in different orders – participants had to listen out for the words and cross them out, with the aim of crossing them all out and scoring a bingo

Workshop 2	Quote boards	Six posters illustrating a range of quotes from Oversight Group members responding to the following topics: risk of a severe space weather event; organisational concerns, challenges or dilemmas; input it would be useful to hear from members of the public; personally preparation; spending priorities
	Scenarios	Task sheets asking participants to consider their response to a severe space weather event in the short term and in an ongoing scenario – in the short term scenario they were asked to think about either a personal or an organisational response (from the point of view of an emergency responder); in the ongoing scenario they were asked to consider societal issues, impacts and mitigation activities
	Options	A list of options for research, systems resilience and communication activities as possible areas for investment – participants were asked to work as a group and divide an imagined pot of resources between the options
Workshop 3	Presentation	PowerPoint slides covering the Saturday activities
	Human bingo	Cards asking participants to "find someone who…" designed to encourage mingling pre-workshop
	Pub quiz	A quiz to be undertaken in teams, covering the topics of science, impacts and resilience in relation to space weather
	Research options	A list of research options relating to space weather, including a mix of options suggested by the Oversight Group and those suggested by participants in the second workshop
	Systems resilience options	A options for improving systems or technological resilience to space weather, including a mix of options suggested by the Oversight Group and those suggested by participants in the second workshop
	Awareness and communications options	A list of communications options relating to improving understanding and awareness of space weather, including a mix of options suggested by the Oversight Group and those suggested by participants in the second workshop

Appendix 10

SPACE WEATHER OPTIONS AND PRIORITIES

As part of workshop 2, participants discussed a range of options for mitigation or research around space weather (1 to 10 below) as well as adding any additional ideas (11 to 16 below). Two groups at each workshop (six groups in total) discussed the options and they talked about how they would divide up a limited fund between the options, with each group having 15 tokens to divide between the options (90 tokens in total). The output is summarised below.

Option	Total allocation of resources (out of 90)	Comments
IMPROVED FORECASTING		
1. Improved modelling of geomagnetic storms	11	Important to be able to predict
2. Observation, data collection and analysis to improve understanding of extreme solar events and their frequency	10.5	Prediction is important to enable preparation. The basis for everything. Important to have data to back up communications, and good to have the history
3. New satellite systems to allow increased monitoring of sun's activity	18.5	For better observation, could help the warning system. Could share funding internationally.
4. New ground-based systems to allow increased monitoring	8	Would improve forecasting and build up a history of events, mix of views on how important it is.
INCREASED RESILIENCE OF EXISTING INFRASTRUCTURE		
5. Improved operation of existing aviation communications systems based on HF radio	0.5	Share with business (e.g. government match funds), or airlines to pay. Why is this not already happening?
6. Alternative aviation communications systems such as satellite communications to replaced HF radio on transoceanic routes	1	Business should pay. Why is this not already happening?
7. Increased stock of high voltage transformers in each UK region	8	Some say business should pay. A mitigating action for a range of scenarios. Government should insist power companies have these in place.
BETTER INFORMATION SHARING		
8. Increased business awareness and preparedness through information sharing within sectors, e.g. finance, transport	6	Good value/low cost, and important, links to taking personal responsibility. Business have to take some of their own responsibility.
9. Increased public understanding of space weather risks through including space weather on school curriculum	7	Low cost and important, links to taking personal responsibility. Kids take information on board better and will tell their parents.
10. Increased public awareness and preparedness through communications campaign.	9	Only good if you have something to tell people. Low cost and important, links to taking personal responsibility. Spend more money creating awareness.

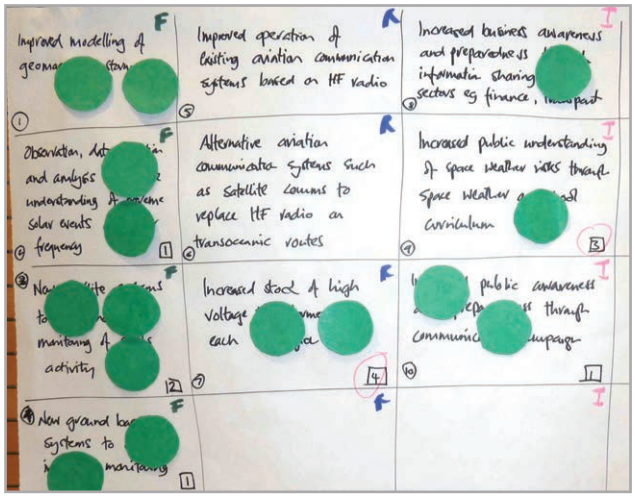
OTHER		
11. Investment into sustainable resilient infrastructures / Localised alternative power systems / Reduce dependence on oil	2	Other options assume sticking to the norm.
12. Alternative time signals for GPS loss	1	
13. International collaboration	1	
14. Other public spending priorities	3	Included in one group to show that there is a wider context to consider
15. Better resilience of emergency services communications	1	More important than improving communications for people flying over the pole
15. Funding for school leavers to help them get into science, e.g. apprenticeships	1	
16. Funding for public/private investment / collaboration on wider consequence management	1	

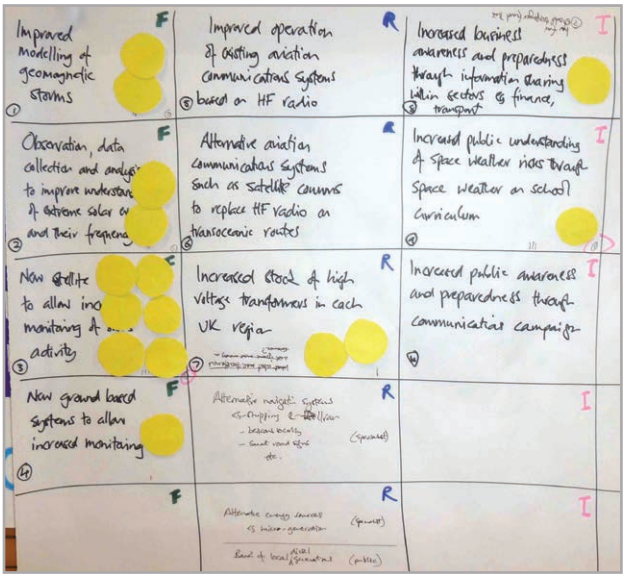
Other options for increased resilience of existing infrastructure discussed here and during other conversations included:

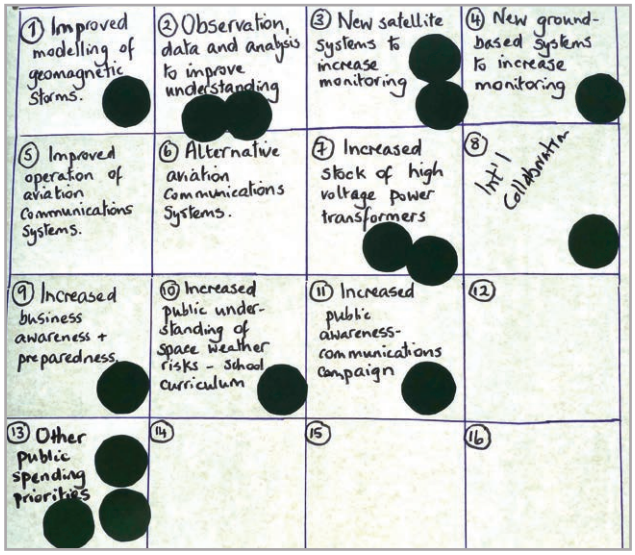
- Identify vulnerable areas (e.g. rural hospitals) and prioritise contingency plans/measures in these places.
- Work with insurance companies to clarify their position on damage to technology or systems as a result of space weather
- Invest in local or micro- power generation, e.g. solar power or diesel generators for vulnerable communities, local wind power, solar panels on supermarket roofs
- Build in resilience to new buildings and developments
- Pool data, e.g. on customer electricity usage, to build a fuller picture of possible systemic impacts
- Invest in more sustainable / resilient alternatives to existing infrastructure and systems, e.g. communications systems for emergency services, alternative navigation systems, alternative energy systems
- Ensure alternative time signals to deal with GPS loss are in place

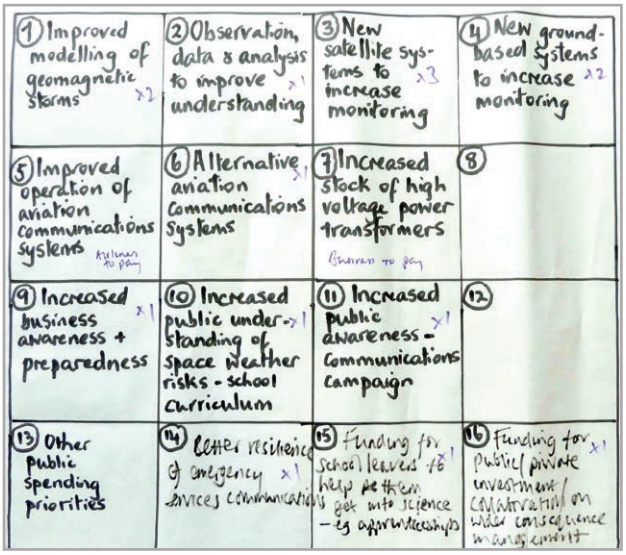
Figure 1 below provides a visual picture of how the groups at the three workshops responded.

Figure 1 Spread of resources across the three workshop 2s.









In workshop 3, the options discussed in the workshop 2 prioritisation exercise were added to with suggestions made by participants in previous workshops. The options for resourcing were then divided in to research, systems or technological resilience, and options related to increasing awareness or understanding. These were discussed in turn with a view to gaining a deeper understanding of which options this group of members of the public favour and why.

Research. The table below shows the list of options discussed (with specialist input) alongside comments made by members of the public.

Option	What do you think?
1. Improved **modelling** of geomagnetic storms, with longer term goals of improving predictions and developing a model of Earth's magnetic field	• Generally, members of the public may think: should we be worried? Not going to happen in our lifetime? • Like a tsunami – last major one in 2004. Early warning systems in place. We ought to be able to have some early warning system for space weather – this is the view on the basis of what we know. • Icing on the cake – implies investment in 2,3,4. Gives better modelling. • Is it the volcano scenario – spending money on something that isn't predictable? • Already have some 1 and 2, but need satellites. Do it all or separate? International approach – shared costs. • Yes – prudent to spread money out along complimentary areas of research. Need data to back communications and actions up, e.g. if impacts occur we will be better prepared "this is what we think will happen and this is why."

2. Observation, **data collection and analysis** to improve understanding of space weather and its frequency	• No longer "beyond our comprehension". Wouldn't have been able to express opinion without that knowledge. • To model you need the data • At what cost – finance should be at the top for this • Could utilise crowdsourcing
3. New **satellite systems** to allow increased **monitoring** of the Sun's activity	• Priority – go for 3 and 4. • If there was something of the power of the Carrington event coming from sun – having technology up there might give more time to kick into action and communicate
4. New **ground-based systems** to allow increased **monitoring** of the effects of space weather	• These are cheaper, but data not as immediate at ground based system – perhaps too late. • If ask other countries to fund – any knock backs? [Yes though more a question of who's first at the table – how to tie in all those] Very useful to have the info from a reflective perspective – in retrospect – but still useful. • Could have in back garden. Could be replaced easier. Once again getting people together with an interest and sharing info.
5. More research on replicating impacts (e.g. on electrical systems) to understand and mitigate effects on technology	• Worried about the expense/waste of destroying expensive equipment – need better argument. • Hard to model knock-on effects. GPS/telecoms/electricity are key. New for emergency planning community. Could model response without GPS – do drills. • When events occur you will see the impacts. But makes sense to do tests – could make a large difference to the general public. Need basic understanding of the impacts before you invest in bigger tests etc. Would knowing what it meant to you help? If putting something (money) in want to know what you are getting out.
6. Share data from different research projects	• Good idea to share data, and between countries. • Scale and data – need to explore beyond the edges. • Seems to be improving, but there are barriers – politics, commercial issues e.g. privately funded organisations.
7. Go back to historical data to help with prediction	• Should be low cost option – go for it. • Potential crowdfunding citizen science project. • It's another useful layer of data and a nice way of involving the public.
8. Model the effects of 'Carrington times 10' to understand extreme scenarios	• The question is not clear – is it 10x event or 10x impact? • Hard to predict – where draw the line. Risk register – "plausible risk". But what's the event that's more than 1 in 100 year? What is plausible? • Could it happen? Isn't it always part of the risk analysis? Would make you better equipped.
9. Improved methods to detect strong magnetic fields developing inside the Sun and to forecast when they will reach the surface	• Isn't this being done already? • Links to 1–4 • Sounds really interesting. Similar to volcanoes – see what's happening.
10. Better models and methods for the journey of CMEs from the Sun to the Earth	• Worth doing. • Also look at other stars. • Useful – another layer.
11. Maintain and enhance the operational space weather forecasting capability	• Keep people informed. Is good. • Look at everyday impacts rather than only scary stories. • Without putting funding here all the info/data would be science/interest rather than operational.
12. **Additional suggestion**: monitoring instruments in current space craft	

Systems / technological resilience. The table below shows the list of options discussed. Participants discussed their level of preference for each option in three groups – the middle column below provides an overall picture of these responses, with accompanying notes to the right.

Option	Preference	Notes
1. Improve **existing** aviation high frequency communication systems	Low to high, with many saying medium, and some saying low for commercial, medium for military	Overall group comments: • Opportunity to innovate. • Are civil aviation systems as good as military? • Rather than shoring up system, use opportunity to innovate. (1 and 2 in tandem) Individual comments from those saying medium: • Not sure necessarily possible but make sense if it is. • Important, but it is a basic safety requirement and should already be happening. • Amount of people using airplanes. Potential threat to life so absolutely. • Aviation industry to fund. • Up to the industry to fund. • Airlines responsibility. • Airlines responsibility. Individual comments from those saying low to medium: • Commercial aircraft delays/cancellation are not really of concern – so few people/not everyone does it. • It would be a pain but not a priority. However ensuring military resilience to loss of HF is more important. Individual comments from those saying low: • Rather than shore up the system, innovate (see 2). But mainly funded by the airlines not government (public purse). • Airlines responsibility, in their interest economically as well as safety
2. Develop **alternative** aviation communication systems to replace high frequency systems	Low to high, a complete mix	Overall group comments: • What is this for – alerting to threat to life or for commercial purpose. Costs? Who pays for this? • Tech already exists Individual comments from those saying high: • Is this possible? Yes. But who pays? Commercial cost? • Alternative system, additional back up, another layer. • Sat comms potentially. • Already available (military and passengers) Individual comments from those saying med to high: • Spreading load, reduce single point of failure Individual comments from those saying med: • Surely these already are – but it's important to have them. • Airlines responsibility. • Airlines responsibility Individual comments from those saying low to med: • Sat comm Individual comments from those saying Low: • Techs already exist – need to use them (e.g. long wave) • Not going to affect loss of life. • If commercially sensitive then industry itself should invest not government. Should make sure it is resilient. But mainly funded by the airlines not government (public purse)

3. Increase the stock of high voltage transformers in each UK region	Primarily low, with a couple saying medium or high	Overall group comments: • Following expert advice from NG! • Depends where and how many in each location and regions not substation • Don't need Individual comments from those saying med to high: • Informed by knowing where they are currently and how many Individual comments from those saying med: • Have stock – maybe questioning location of store (dotted around / closer to more vulnerable area) Individual comments from those saying low: • Already sufficient. • Stock should reflect current opinion of what is necessary. If Nat Grid happy, then so should public be. If scientific opinion changes, then definitely change. • It's already sufficient. • In the right place. • Apparently there's enough if Carrington event occurs. • Already adequate stocks (so we are told)
4. Identify vulnerable areas (e.g. rural hospitals) and prioritise contingency plans/ measures in these places	Primarily high, with a couple of people saying low	Overall group comments: • Quick win if not being done already • Range of opinion. Might have plans, but are they any good? But easy to achieve Individual comments from those saying high: • V important, non-expensive. • If isn't already being done? If not, then definitely a priority. • Low cost solution and easy to implement. • Should be doing this anyway – valuable for many other disasters/ scenarios. • Very important. Relatively easy to achieve Individual comments from those saying med-High: • Plans are in place. Vulnerable people in the community Individual comments from those saying low: • But coastal cities might need more.
5. Work with insurance companies to clarify their position on damage to technology or systems as a result of space weather	Low to high, a complete mix	Overall group comments: • Quick win. • Not sure about question? (Act of god etc) Better to sort now. Will help if it encourages resilience • Commercial businesses look after themselves. What is actually insured? Need to clarify what this is about! Individual comments from those saying high: • Financial loss to satellite area. Need to clarify. Act of God! • Instead – parliamentary legislation on how to define space weather e.g. act of god or not, then each company deals with it individually. • Important to clarify the position – it could cost individuals a lot. • Is that government involvement? Does government clarify what constitutes 'act of god' etc? Individual comments from those saying med to high: • What we are insured for should be clear, know what definite cover there is. Individual comments from those saying low-med: • Responsibility of the companies more than Joe Bloggs.

6. Invest in local or micro- power generation, e.g. solar power or diesel generators for vulnerable communities, local wind power, solar panels on supermarket roofs	Low to high, mostly medium or high NB one pair said low for communities, medium for individuals	Overall group comments: • Resilience needed in communities. • Range of opinion. High in area of no back up generator. Allow own power being generated to be used. • Should be doing it anyway. Practical measure to improve resilience generally and coopting local communities. Individual comments from those saying med to high: • Resilience should be there – useful for all sorts of risks. Individual comments from those saying med: • Could make mandatory. • Regional differences in effectiveness. • Relatively low cost. And environmental benefits Individual comments from those saying low-med: • Already happening? • Community tech would be expensive, may not be used, not wise investment. But if could invest in individual, personal power supplies, could improve personal resilience. • Responsibility of companies.
7. Build in resilience to new buildings and developments	Medium to high, with a few saying low	Overall group comments: • Depends on e.g. connection to grid Individual comments from those saying high: • Practical measures – employ new technologies for new builds for built in resilience Individual comments from those saying med-high: • Forecasting – better to be prepared from the beginning, new build hospitals. • Solar panels that aren't connected to the grid? Direct into home Individual comments from those saying med: • New hospitals Individual comments from those saying low: • Own generators? • To a point. Cost/benefit. • Yes. Definitely build into public services and buildings – make obligatory. Not such a problem for domestic buildings. • If something doesn't happen very often…how much would it cost to proof every building?
8. Pool data, e.g. on customer electricity usage, to build a fuller picture of possible systemic impacts	Low to high (tends to be either low or high, rather than medium)	Overall group comments: • May already exist • Power companies may not be willing. Linked to number 3 – if know where weaknesses are then might have impact – smart meter info if can. Individual comments from those saying high: • Link to 3. • Who pools data and responsible for taking action – government or National Grid? Individual comments from those saying low to high: • Won't cost too much and monitoring must already be done. • It must already be done/common sense. Individual comments from those saying low: • May have already. • Good idea – how willing would companies be to take part? • Relevance?

9. Invest in more sustainable / resilient alternatives to existing infrastructure and systems, e.g. communications systems for emergency services, alternative navigation systems, alternative energy systems	Medium to high	Overall group comments: • Different understanding of what would be involved • Emergency services – using maps etc (will lose the skill) and in emergency have you got time to read maps. Teach people to map read. Not always new tech – go back to watches etc Individual comments from those saying high: • Government incentive or private choice. Emergency services = government. • Yes – if preference to domestic stuff. But needs to be proportionate. Individual comments from those saying med-high: • Training runs with old radio systems and other contingency plans if GPS failed. American system is vulnerable. Individual comments from those saying med: • Lot of money. Like the aircraft situation. Who pays for it?
10. Ensure alternative time signals to deal with GPS loss are in place	Low to high, complete mix	Overall group comments: • Low – don't care about bank transactions or people losing GPS facility. High – whole system affected over time. • E.g. ships in channel but double fail safe. Single point of failure. Whose responsibility – is it gov? Felt industry. So, it's important but put cost elsewhere • Might be in place. Easy to put into place. Companies responsible. Just do it! / Don't because don't believe space weather is serious. Individual comments from those saying high: • Hard to explain impacts – but back ups are important – shouldn't just rely on one technology – and the back ups may rely on GPS through unforeseen dependencies. Individual comments from those saying med-high: • Finance industry. Phones. Individual comments from those saying low: • Low priority – the major impact of GPS is shipping/transport, not financial impact. • If financial companies are so concerned, they should invest! • Industry responsibility. Atomic clocks for certain info. • Companies should invest.

Awareness and understanding. The table below shows the list of options discussed, along with specific comments from participants

Option	Notes
1. Add space weather into the school curriculum	• Awareness of fire brigade • Which subject? Science/geography • Aware of event and impact of it • When learn about solar cycle and common consequences • Generally positive, but some disagreement about the age at which space weather should be introduced into the curriculum: introduce the idea from early on, say five years. "Children are like blotting paper: they have great imaginations and absorb ideas". But, why would you want to frighten them? You should wait till they are older, in secondary school.
2. Add 'coping in an emergency' to the school curriculum – i.e. dealing with the consequences of emergencies, including space weather	• Yes. Teach self sufficiency/responsibility • Kids communicate. Like PSHE • Response of teachers. Need package/resources etc. So might be better to do it more informally – guest speakers etc, workshops. Year 3,4,5 and Scouts. • It would be good to build on the idea of coping with emergencies and encourage people to think positively about emergencies. • Dealing with emergencies is already on the curriculum? • Some rethink regarding the question of the age at which space weather should be introduced to children: you should introduce the idea of coping with emergencies early so that it isn't so threatening. • Hope this was happening in schools already – should be talking to children about coping with emergencies from an early age, talking about space weather science is something different.
3. Increase information sharing within sectors (e.g. finance, transport etc) to improve awareness and preparedness for space weather events	• Prompted discussion about insurers, Bank of England and other events
4. Communicate with businesses about the need to create contingency plans (and potentially staff awareness about space weather), so that every business has an emergency plan	• Any additional measures due to space weather? Are exiting measures good enough? • What do businesses know? Not a lot! Who does it?
5. Develop a communications campaign to increase overall public awareness about space weather	• Online journalists. Ads. Social media. TV – Horizon special.
6. Increase communications and activities around personal and community resilience more generally, not necessarily tied to space weather	• Get people used to the idea via 'Aurora', then if something happens, there is familiarity.

7. Focus space weather communications on impacts / how it might affect people's lives in order to get them interested	• E.g. Y2K, ozone hole, climate change: drip feed over time • Balance between scaring and being prepared. • "What do you want people to do if there's a solar storm?" • This is a good idea, but avoid scaring people.
8. Don't call it space weather	• One group said no to this • Another felt it was a good idea to call it something different, as 'space' raises the idea of something unknown – it makes you think of black holes and things disappearing. Sense that 'solar activity / impacts / effect' or similar might be preferable
9. Introduce a 'space weather drill' similar to a fire drill	• People didn't like this option. (e.g. this would be relevant if it space weather were something that happened regularly, but it is counterproductive otherwise. It might be relevant to have drills of emergency plans)
10. Raise awareness gradually rather than via a campaign, e.g. drip feed information via the news / via trusted sources	• Liked this • Another commented this was a mix of other options (11, 12). No-one proposed a strategy for drip-feeding information.
11. Develop a computer game like Sim City but with space weather scenarios / impacts	• One group didn't like this. • Another said it would be a good way of giving children information about the risk, but said computer games talk about things in a different reality, so the situation is not taken seriously. Uncertainty over whether people would buy it (but see 16 below)
12. Have a Panorama programme, documentary, soap episode or a short slot (like a party political broadcast or advert) on space weather	• Connects to 10, discussed in 1 and 2. • There was some difference of option whether having a Panorama programme would be part of an information campaign option (Option 5) or a drip-feeding of information campaign (Option 10). One participant objected to the option of an information campaign: "campaigns don't change understanding in the long term. How are you going to change people's psyche?" This participant then suggested an additional option, which others seemed to agree with (21 below)
13. If a severe event happens with minimal impact, focus on communicating what was done to prepare and lessen impacts – to avoid the 'crying wolf' scenario	• General agreement with the need to avoid being seen to be 'crying wolf' when there are so few impacts to be seen.
14. Send every home some literature about space weather, possibly followed by a TV slot (e.g. someone from government) to explain more	• NO!
15. Educate people about normal Sun activity	• Yes • Good idea. E.g. video of solar stream coming from sun – gives context. Make it less scary – know what's normal.
16. More information in museums	• One group said no to this idea • Another discussed the benefits of hands on activities like those at Jodrell Bank as a good way of engaging people. Maybe plot a CME in an app. Put it in a game/app.
17. Posters, e.g. BGS poster about space weather, posters with the top 6 things to have in an emergency box	• Yes • Glossy space weather poster for science labs, library. Useful for schools. For community centre. • Also poster on emergency situations, with space weather as one thing.
18. Provide funding to train school leavers in space weather-related disciplines	• Not really liked. If kids learn about it in schools – then use this to train the community. Have to be interested in science first and then have to have opportunity.

19. Have a regular space weather slot on the weather forecast	• Liked by one group • Another group also like the idea and discussed in more detail: – To get familiar with it – most people watch – will be surprised what new info will get. Forecasts have mentioned it. Drip feeding little bits and often. – How regularly? E.g. pollen count – only when raised/relevant. Pollen count used to be less regular. Initially e.g. once a week and then more regularly. It's the impact. – Drip feed rather than link to impact – gets people accustomed, so as not to panic. – Also positive things / celebration, e.g. northern lights. – Why put it in weather? (When not linked to weather). People may associate it with weather though (possibly because of the phrase space weather). Met Office could be seen as centre for hazards? And use Met Office not journalists as more trusted? More reliable source. Know forecast – every day @ set time – easier to know where to look. – Currently only mention as link to northern lights/clear sky and if big impact would move into news. – Would have it in weather – not just adults, children – could be short, educational, in news or after – update on space weather. – Because of name – most people would think weather. – NB not just TV – bigger role for social media? Think about why, what, best channel? Can get message out in different ways.
20. NEW: Promote better understanding of risk	
21. NEW: Support communications around local resilience	• This seemed to reflect thinking that space weather is not that different from other risks. • Do people need to know that space weather is responsible for certain impacts, or just know what to do?

At the end of the final workshop, participants (members of the public and specialists) were asked to express a preference for resourcing priorities in relation to space weather. The results are shown below in figure 2. A caveat to this picture is that it does not account for subtleties around, for example, sharing the costs associated with each option with other countries or other non-space weather budgets. It simply gives a snapshot in time.

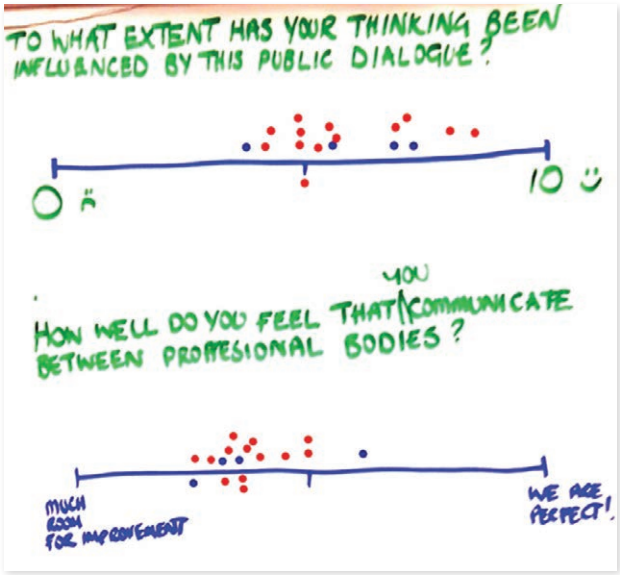
Figure 2 A snapshot in time of participants' space weather resourcing preferences.

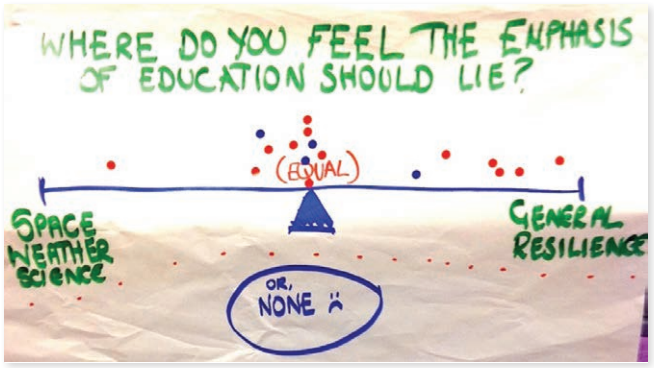
Appendix 11
STAKEHOLDER SUMMIT SUMMARY REPORT

STAKEHOLDER SUMMIT

Wednesday 15th October 2014, 10am-4pm
The Cosener's House – Abingdon

TRANSCRIPT – DRAFT 2





The three questions shown above were asked by a member of the public who attended the stakeholder summit, having previously been involved in all three public dialogue stages as a participant. All stakeholders attending the summit responded to the questions by placing a dot on the scale in the position that best represented their view.

Contents

This report

This report has been produced by 3KQ on behalf of the space weather public dialogue Oversight Group. It largely retains verbatim comments from the meeting, so is labelled a transcript rather than a summary report. The content of this report in the form of potential actions and commitments from the various stakeholder has been used to inform the final report of the space weather public dialogue (published separately).

1. Attendees

Specialists

Alison Crowther	Sciencewise
Alison Fleming	Leicester City Council
Chris Frost	STFC
Chris Scott	University of Reading
David Wade	Atrium Space Insurance Consortium
Geoff Darch	Atkins
Helen Chivers	Met Office
Ian McRea	STFC
James McBride	Civil Contingencies Secretariat, Cabinet Office
Jim Wild	Lancaster University
Jonathan Rae	University College London
Mark Gibbs	Met Office
Marsha Quallo-Wright	GO Science
Mike Hapgood	STFC – RAL Space
Mike Willis	UK Space Agency
Poppy Leeder	Natural Environment Research Council
Robert Massey	Royal Astronomical Society
Sarah Smart	STFC – RAL Space
Stuart Clark	Freelance Science Writer

Members of the public

Alan McColl	Wrexham attendee
Frances Bowie	Edinburgh attendee
Jacqueline Cummings	Reading attendee
Jen Walker	Wrexham attendee
Monica Holder	Reading attendee

Project team and evaluator

Carl Reynolds	3KQ
Helen Fisher	3KQ
Jane Dalton	3KQ
Paula Orr	Collingwood Environmental Planning
Alex Plumb	Icaro (project evaluators)

2. Purpose and agenda

The purpose of the space weather public dialogue stakeholder summit was to consider the implications of the dialogue for a range of interested organisations, in terms of priorities, policy and resourcing.

Agenda

9.30am	**Arrive**
10.00am	**Introduction** Introductions and the purpose of the day.
10.15am	**The dialogue process** Overview of the process used in the dialogue and its connection to the objectives. Carl Reynolds, 3KQ

10.30am	**The public participant journey** Presentations on the learning and thoughts of public participants, Alan McColl, Jennifer Walker and Frances Bowie, followed by questions to be fielded by participants from Wrexham, Reading and Edinburgh.
11.00am	**The findings of the dialogue** Presentation on the findings of the dialogue, followed by discussion and questions. Helen Fisher, 3KQ
11.40pm	**Next steps 1 - What level of public awareness is needed?** Discussions in groups on the different audiences, what level of awareness is needed and how this might be achieved.
12.10pm	**Lunch**
1.00pm	**Next steps 2 - What is the appropriate level of preparedness?** Discussions in groups to confirm key ideas for personal and community preparedness and the support needed from business and various levels of government.
1.40pm	**Next steps 3 - What new knowledge is needed?** Discussions in groups to consider: lead time for warnings; accurate forecasts; effective responses to impacts; better understanding of how people respond to risk.
2.10pm	**Next steps 4 - What are you planning to do as a result of the dialogue?** Discussions in groups to consider future actions.
2.40pm	**Evaluation** Overview of the evaluator's task and timeline, followed by an evaluation of the day.
2.50pm	**Break/End**
3–4.00pm	**Oversight Group meeting** (reported separately)

3. The dialogue process

Carl Reynolds, 3KQ, gave an overview of the dialogue process. This was followed by a brief question and answer session. This covered two points:

- The need to take a step back and look at the outputs in their entirety, rather than just focusing on the events you went to.
- The need to avoid group think during today's meeting.

4. The public participant journey

Some members of the public who participated in all three rounds of dialogue workshop attended the summit to provide some firsthand input and feedback. They spent some time summarising their experiences, as outlined below, followed by a question and answer session.

Participant 1 shared some 'dots on scale' exercises with the group, as this was a method that had helped to focus public participants' own thinking in the workshops. There were three questions:

- To what extent has your thinking been influenced by this public dialogue? (0 to 10)
- How well do you feel that you communicate between professional bodies ('much room for improvement' to 'we are perfect!')
- Where do you feel the emphasis of education should lie? (more towards space weather science, or more towards general resilience)

The first page of this report shows the results of this exercise.

Participant 2

"When I was first asked to do this, I had to Google space weather. I didn't put the two words together before that, and when I Googled it, it made me think about Hollywood, disaster movies etc. I didn't know anything about it. The way it was developed has made me aware. It made me think – from talking to friends and family – that in a rural area, we get power cuts and don't think anything of it. You assume it will be back on. Now I look out of the window and think about it – if something can knock out power etc, I would have no idea what to do, where to go. It made me realise I probably wasn't prepared for anything like this. I assume it would be brief – if someone said it'll be two days, I would want to know more how long it's going to last than what's caused it. It really was an eye opening process in terms of learning. And as the meetings went on it started learning towards 'right, what would you do, and what would you expect others to do'. Now I think I'd have a grab bag, and the main thing I took away from it was education. If kids are taught about it… I learned about the Sun, but I think looking back if I came out of school knowing about this I might start to be prepared and would start to prepare my family. I think if we prepare more for it now, we will be better able to cope."

Participant 3

"My initial reaction was that I'd never heard of it. I am interested in all things to do with natural phenomena, and I immediately thought of the Big Bang Theory, and wondered what space weather was as opposed to just weather. Of my friends and family no one had heard of it, and some thought of it as being way removed from everyday life. My first thought was that it was a privilege to be part of such an event, at a prestigious building like the observatory. The visual aids were helpful, and we learned there is such a wide range of disciplines involved. I learned what space weather is – that it relates to the Sun's activity and has always existed, but that with our increasing reliance on electricity and technology and plastic cards it is becoming more important. I learned it can only be predicted in the short term, and that there was currently little dialogue between specialists. For the homework we were asked to cope without electricity for 24 hours – I turned it on its head and wrote down whenever I used electricity. At the second meeting we discussed ways we could prepare for blackout. And we discussed vulnerable groups, communication ideas etc. Leafleting was not thought to be viable. And the government response in all this – police, fire and ambulance – none would be able to function. The time of year of an event would make a difference. And there are more people living alone now. I realised the purpose was to think about the response to such an event rather than the science of it. Jodrell Bank was a fascinating location and definitely worth a more in depth visit – it gave a sense of other worldliness. We talked about resilience strategy, for example having a physical point of reference for communities, headed by someone with local knowledge in rural areas. In cities there would be far more disruption to transport etc. Questions are: can the physical size of impact and area be predicted? Do we need to know where generators are located? We talked about communication methods, for example the school curriculum. How about a one week awareness raising about what to do in the event of a blackout – for example supermarket stands with wind-up radios."

QUESTIONS AND ANSWERS

Risk appetite

Stakeholder: I have a question around risk appetite. I generally get the impression members of the public are becoming more intolerant of failures, in terms of flooding etc, yet we are hearing a lot today about the need to be prepared. I suppose the question is 'are you willing to have this, or are you willing to pay not to have it'? i.e. paying for infrastructure to be more resilient.

Public participant: We had a really diverse group of people and we had some who would be happy to pay extra, but for others it was about understanding why things were important and what money would be spent on. Others said don't spend money. There was a range of views, and it's about finding the balance. But across the group there was a feeling that educating about 'what is going to be accomplished and why' would make it easier to spend the money.

Public participant: I would be more than happy to look after myself and my immediate family as long as I knew there were plans in place and it was being dealt with. As long as someone is fixing the problem, I'm more than happy to meet in the middle and do my part.

Public participant: I would prioritise my family, and other vulnerable people.

Local resilience forums

Stakeholder: Space weather will certainly be featuring in our (local resilience forum) planning now. I was really pleased to hear the messages that people were engaged, and specifically that the first thing people would need to know is how

long will the outage will last before they know what's caused it.
Public participant: It would be good to know groups like yours (local resilience forums) exist and communicate it more across the country.
Stakeholder: The Government is asking local resilience forums to do more to communicate, and hopefully we will be raising our profile.
Public participant: Do you depend a lot on volunteers? (Referencing a specific Local Resilience Forum)
Stakeholder: To a certain extent. For example, there are a lot of emergency services representatives, but we are also looking to recruit a different type of volunteer – those who are active in their local community. The Pitt report was really about empowering communities to help themselves, and we are working with that in mind.

Nature of information

Stakeholder: What was your interest going out of this – space weather or general resilience? Is space weather something special?
Public participant: Personally, resilience. Space weather for me is still quite academic. The impacts could be initiated by all sorts of things.
Public participant: I started out thinking it had to be more education on space weather but as we went through I thought more broadly that more could be accomplished by more (not completely) emphasis on resilience, but alongside impacts of space weather as part of that. As part of the homework, instead of doing a physical 24 hour switch off I did a virtual five day switch off and talked through the thought process, and took that into dialogue with my daughter's school. And the school identified areas where they could slot this into the curriculum. For example drawing Earth's magnetic field. It is very easy to slot in specific information about space weather with minimal / no cost or impact on the curriculum.

Forecasting

Stakeholder: I would like to ask where forecasting comes in. If we had a better understanding of when an event would occur, would that count as resilience or communication / education?
Public participant: I don't think you can separate out the two.
Public participant: Resilience is something that shouldn't be temporary – for example look at the San Francisco website on resilience. Forecasting is more useful for dealing with immediate things. Resilience is about longer-term preparedness, and having things in place.
Public participant: Forecasting is important to help understanding.
Stakeholder: Is what I'm hearing that resilience is something you could have where something like this could happen and you would be fine, but perhaps forecasting is about assessing risk on an ongoing basis? Do we want to put effort into having a constant feel for how likely this is, or are you happy for it to happen out of the blue but be better prepared for it?
Public participants: Both.
Stakeholder: I went to all of the locations except for Wrexham, and there was a theme around drip- feeding information. There was one thing about being informed and prepared. Another about forecasting. It felt like a case of 'I will if you will'. Then there was the infrastructure, and that was felt to be slightly less important I think.

Communication

Facilitator: Having been in some of these dialogues and seen what other people are doing, was there anything novel? Stakeholder: Some of it was. And I think it's a really mixed bag – some organisations in this room communicate regularly and very well, and that's a bit to do with communities of interest.
Stakeholder: We are encouraged to think about influence when we put proposals forward now.
Stakeholder: It's also about getting people to think about risks we're not aware of or can't see.
Stakeholder: We probably need to look at barriers between communications too – some of it will be commercial aspects etc. There are parts of science and research where commercial interests work very well and perhaps we're behind. E.g. medicine has much more two way dialogue than infrastructure operators. And we can perhaps start with one-to-one conversations and move on from that.

5. The findings of the dialogue

Helen Fisher, 3KQ, presented some headline findings from the dialogue. The presentation and the question and answer session that followed are summarised below.

PRESENTATION

We experimented with a range of exercises. A key thing for us was having a really engaged Oversight Group and other specialists. This really enabled the process to go as planned and helped the building of a dialogue between specialists and members of public.

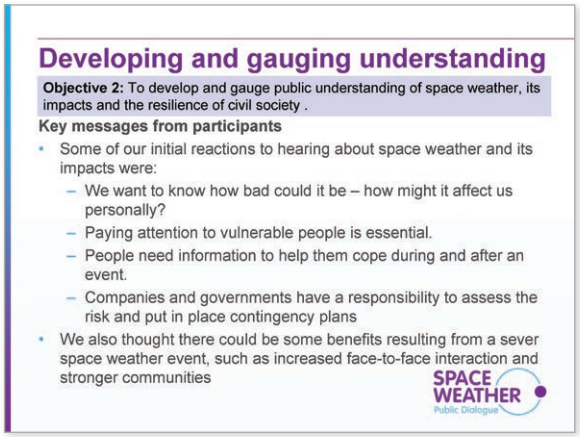
In terms of credibility, you will have to gauge for yourselves having seen the outcome and the evaluation report. We hope that you will all take things away from this – actions and commitments.

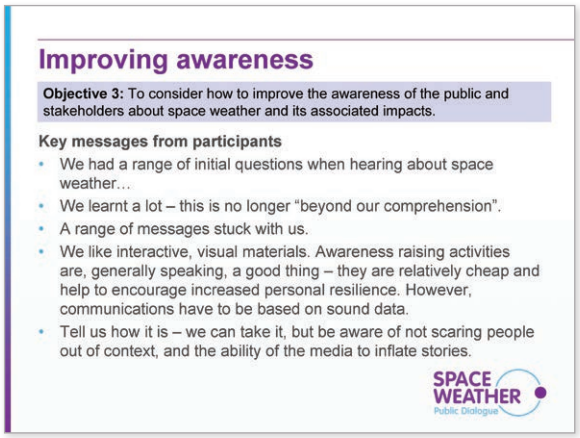
We initially asked participants to think about space weather, what it is and its impacts. We looked at initial reactions. Initial reactions were around things like 'what does it mean, how bad is it going to be, how might it affect me?' One key message was around vulnerable groups – identifying them, knowing about them, how to look after them. Another theme was information – tell us about it and how bad it might be, plus clarity over the responsibilities of Government, companies etc.

One thing that came up was the sense of community and positive impacts it could have by bringing people together. This was unprompted – this idea about community resilience not just in preparation for an event but as a consequence.

We thought about how much information people can handle, and the first workshop threw a lot of information at the participants. By and large the capacity for people to take on board information was really high, certainly when they came back to second event the process of 'inform-check-discuss' was really working in terms of getting people to the point where they could have informed dialogues about topics such as public spending. Touching on the idea of drip-feeding – familiarising people with the terms space weather and resilience. We talked about other areas where this has been done e.g. climate change, carbon footprint, and so on.

There was a range of messages that stuck with people. These included resilience, and whether space weather is a useful phrase to use – the main point being that if it's all coming from the Sun why don't we talk about it as 'Sun' as opposed to space. The education message came through again and again: if you can talk to people about things like this from an early age it makes communication easier.

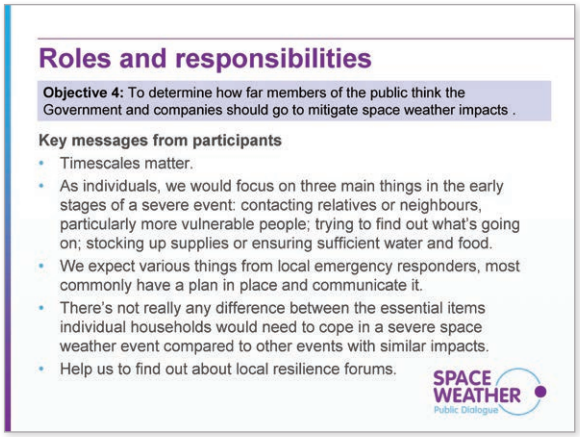




In terms of specific materials that worked – people like visual, interactive materials. It was felt that, overall, awareness-raising activities when compared to other spend (resilience, equipment etc) is a bit of a no-brainer. Increased forecasting was seen as important because participants felt if you are going to tell people about space weather you need to know that what you're telling people is based on sound data.

It seemed like people were saying, 'we're not more scared because you've given us this information, so tell us how it is, but it needs to be in the context of telling us what's being done about it and what we can do about it'. There were a few conversations that touched on the ability of the media to blow up or exaggerate things beyond reality.

Timescales matter – this was a message in two respects. Firstly, it was felt that actually this wouldn't be so bad at first, but when you go into three or four days plus, the systemic impacts on transport, food and so on become a bit more worrying. Secondly, people suggested they wouldn't be concerned at first, but when you start to talk about an event going overnight and into two days it stops being fun or exciting and becomes much more worrying. The 12-24 hours period seems to be the point at which worry starts to set in.



As individuals there were a few things that were consistently focused on:

- Contacting relatives/neighbours.
- Finding out how long it's going to last or what's going on.
- Stocking up on supplies – caveated by knowing how long it's going to go on for.

This went alongside the expectation of emergency responders having a plan in place and making sure they communicate it – this came up several times.

In terms of personal kit, there wasn't much difference between what people thought would be needed in a space weather kit as opposed to a kit for any other event with similar impacts, so there was a sense of the need to be prepared generally rather than specifically for space weather

Lots of people didn't know what local resilience forums were or that they exist. Is it about them getting out into the community and telling people that they exist or just more about knowledge? We didn't really talk about this at that level.

There were three focuses to discussions on priorities: improved forecasting; technological/systems resilience; and communication, awareness and education.

We asked people 'what do you expect to happen with your views?' They expected these to be taken into account but said it was now over to the relevant organisations. We would ask you to consider the following: does it challenge you, make you think anything new, confirm what you thought etc.?

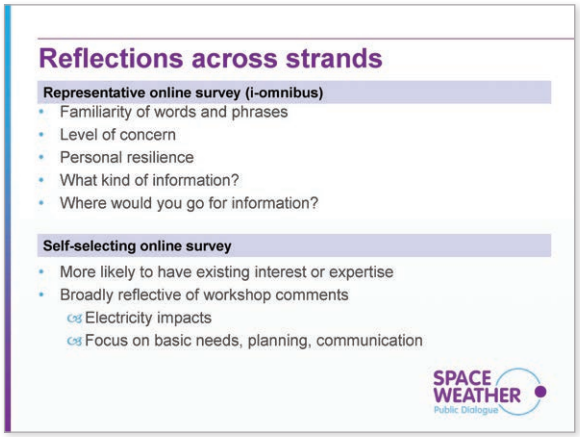
There is a strong message about personal resilience – we should all think about increasing our own resilience, but there is also shared responsibility. I.e. if I'm going to do something I also expect governments and other organisations to be doing things by way of support.

Participants talked about investment in the three areas, and all were felt to be important for different reasons:

- Forecasting/modelling. This was felt to be important because if you are going to communicate more about space weather you need something to back up assertions, as well as the fact that better forecasting might give us more time to prepare.
- Systems resilience. This was thought to be sensible but participants said the bill shouldn't just be footed by Government or the public purse, and that companies should pay for (all or partially) their own resilience measures. Participants tended to be open to more systemic measures such as building in systems resilience to new housing developments, back-up solar generators, and so on. So systems resilience was seen as generally a good thing, but there were questions about who's going to pay for it, and the suggestion of thinking more creatively about building in future resilience
- Education. This was consistently felt to be a good idea, specifically drip-feeding and familiarisation, building into the national curriculum (resilience generally), and possibly building into general weather forecast (but there were a number of questions about how this might work in practice).

Participants suggested that linking the community up with local resilience forums, or generally raising awareness that they are there, would be a good idea.

Self-selecting online survey. This was open to anybody. To date there are 67 responses, with many indicating they had an existing level of knowledge or interest. Interestingly, the things they talked about were reflective of what was heard in the public dialogue workshops – electricity, clear planning/communication between the key agencies, and so on.



Representative online survey. This included 1,010 participants representative of 16-75 year old adults in UK. Results showed that space weather is not a familiar term, or if people had heard of it they don't know what it meant. There was, however, a lot of familiarity with specific words and phrases associated with space weather. Respondents said they would be slightly more concerned if they knew a power cut was caused by space weather as opposed to normal weather. In terms of the timescale of power cuts, between the 12 and 48 hour mark the weight of people shifted to the negative in terms of preparedness and ability to cope. The type of information people would seek tended to focus on: impacts; what people can do personally; what causes it; what everybody else is doing – so this was more focused on impacts and the immediate aftermath than on knowing more about space weather. In terms of seeking further information, Internet search engines and the Met Office ranked highest as preferred sources.

QUESTIONS AND ANSWERS

The key points from the question and answer session were as follows:

- It's hard to tell how many people bring personal agendas to the table in the self-selecting survey – people do tend to respond with some degree of existing interest, so you do need to filter it. What was interesting was that a lot of what they were saying did broadly reflect what was heard in the workshops.
- I-omnibus participants get points to incentivise them to take part. Over the years there have been comparisons with face-to-face data, but given the nature of the questioning (a range of topics on disparate issues), there may be subtle differences of biases in the way people respond.
- There was limited discussion around satellite navigation impacts. The question was raised a few times, but people tended to go towards electricity in the homework, as it is perhaps easier to focus more on electricity impacts because they are more tangible. Also, industries such as the avionics and banking didn't have an input as they were not present – this may have steered the conversation in a different direction.
- Accessing older people via an online survey is not so much of a concern in the research community these days – the concern is more likely to be around groups such as under-privileged people. The representative survey did not pick up vulnerable people in their 80s/90s (it was representative up to 75), but even a face-to-face survey might struggle to recruit that age group.

- This project does not include specific separate dialogues with business. Local authorities have responsibility to engage with industry around business continuity e.g. impacts on sat nav, electricity outages, etc. Government has ongoing communications with businesses in relation to topics such as health and transport, so there is a constant ongoing dialogue with businesses, although not formal research.

6. Next steps 1 – What level of public awareness is needed?

Attendees spent time at their tables discussing the question above in relation to the dialogue outputs. The key points fed back to plenary are described below, followed by full notes from the table groups.

- Not convinced space weather as part of a forecast would work on a day to day basis as people might switch off.
- Maybe there is a need to raise awareness through the media but cover as many bases as possible – e.g. Radio 4 and Newsround. Then you pitch how you're telling the story and informing at that sort of level, so you are covering the whole base.
- Have positive media output to counter sloppy journalism – make sure space weather isn't just the bad space weather, but also the good or positive aspects such as the northern lights
- The tolerance of members of the public will be affected by their understanding. For example if you're stuck in traffic jam and you know there is a fatal crash in front you're less likely to be annoyed than if you thought it was due to road works or congestion.
- There could be some very simple quick easy education projects – e.g. jam jar magnetometers. It is just matter of looking at where to fit them in. This is something kids could do at home and tell their parents about. Also, if you are going to have a forecast or announcement, it's a way of saying this is a tangible thing and you can see something physical happening. Those projects do exist – e.g. giving magnetometers out to schools and getting them to do real-time space weather forecasting.
- It would be good to have as much notice as possible – three to four days is not yet possible.
- How do we get the information out? The Leicestershire Resilience Trust is going to use a model from Lancashire. But how often are the websites used? By MSc students. But who else and how?
- Understanding the diversity of impacts is important – e.g. weather effects beyond extreme scenarios. Also there are fairly ongoing effects (e.g. aircraft diversions) that are a normal part of resilience to these things. Should people be told their plane has been diverted because of a solar storm?
- Levels of awareness – you have to explain what those levels are. For example do you actually know what levels of terror alert mean?
- We live in a country where extreme things don't tend to happen, so people aren't used to having to be resilient. How do you educate people? Flooding is the one thing we do have, so how do you get people not impacted by flooding to also be prepared? Rural communities are used to being cut off, but it never happens, say, in the centre of the city – it's getting those people who aren't normally impacted to be resilient. It's about building up the resilience muscles.
- In some ways we're not capitalising on opportunities to communicate better – e.g. during the recent possibility of strong space weather, the Met Office made a strategic decision to talk about the positives of seeing the northern lights. But there is not a library of great images or graphics to use. Also we need to create some things – they don't all exist. But no one has the money to put into these things. Some organisations are good at sharing.

Awareness – notes from table 1 (as written)

Awareness – science

- Through media, news (print) stories, Newsround etc – need to pitch/cover as many audiences as possible. Use 'good' journalists i.e. science correspondents.
- As much notice as possible of an event.
- Government does need to play a part in educating/introducing people to the science.
- Introducing it through the national curriculum – although not necessarily as a subject in itself; perhaps a taster or in association with another subject such as physics and magnetism. Could be at quite a young age.
- Knowledge of the subject would mean you have some reassurance if something did happen.
- Leaflets are a waste of money; that could be spent better elsewhere i.e. increased resilience.

Awareness - resilience

- Knowing what has caused the problem i.e. no electricity wouldn't change actions but would inform them. But would like to know what has caused it.
- Information to come from the supplier rather than government, etc.

Awareness – notes from table 2 (as written)

- Space weather science or general resilience?
- People want to know. Their tolerance will be affected by their understanding.
- Electricity (and its loss) is not necessarily the priority of focus, e.g. trains can stop through loss of computer function as a result of a space weather event whilst electricity remains.
- Loss of electricity not greatest impact to infrastructure.
- Forecasting and awareness can warn people that failures may occur.
- Space weather is almost the 'worst case scenario' of impact to infrastructure as all happen at once.
- Danger in only talking about big events.
- Regular communication to the public about the sun's activity / linking into something like aurora borealis – you may see this and these could be some of the affects.
- Education exercising the public resilience muscle.

Awareness – notes from table 3 (as written)

- Not convinced space weather as part of weather forecast would get interest. Will space tourism [?] us to start doing it.
- Lessons learned from climate change. What's worked/what hasn't.
- Not talking about end of world – important to ensure journalists report accurately.
- Space weather alerts would be similar to terrorism alert.
- Warnings are a bit meaningless unless you know what risk levels mean. Not sure what terrorism alert levels mean.
- Link to something like chances of seeing aurora to link it to something most people would know/understand.
- Education projects – jam jar magnometer. Schools/citizen scientist projects. Target Key Stage 2.

Supporting materials

Attendees watched a clip from BBC news highlighting the new Met Office Space Weather Operations Centre (MOSWOC), and listened to a BBC Radio 4 clip illustrating how a space weather forecast might sound.

Dr Marsha Quallo-Wright of GO Science introduced a report being developed by the Cabinet Office and GO Science. GO Science has been working with the Civil Contingencies Secretariat in the Cabinet Office and behavioural scientists to develop a check list, in order to ensure that when people are planning risks they are thinking about behavioural insights. This is the first trial of the behavioural insights checklist. One interesting thing that came up was radiological risk – people tend to overestimate this – as well as strategies for countering disinformation on social media. In general a moderate message gets the bottom inches of a column and a sensational story gets the top inches. Behavioural scientists said that trusted people such as the Met Office and government social media accounts can very quickly cut off rumours. The natural assumption can be towards looting, but actually often behaviours are pro-social. The report looks at appropriate messages and trusted individuals, and it came out that Met Office is really trusted. In general it's about challenging the assumptions that government has and making sure all the knowledge that is coming out is being taken into account.

7. Next steps 2 – What is the appropriate level of preparedness?

Attendees spent time at their tables discussing the question above in relation to the dialogue outputs. The key points fed back to plenary are described below, followed by full notes from the table groups.

- The now and ongoing challenge is the drip, drip, e.g. putting space weather into Met Office weather, but also the idea of a single box when you talk about flooding, or space weather, or other things. It's about the overall idea of resilience.

- At 24 hours it would be useful to be told there is a CME on its way, and then half an hour beforehand to know what it's going to do. That way people could change their behaviours (e.g. working from home) or be on alert (e.g. nurses). The half hour warning for companies would be very useful.
- How much is business worried about preparedness versus how much they insure against losses? Satellite operators are insured for space weather problems only if it's an outright failure. A lot of other areas of business wouldn't be covered, although they might be covered by something like a business interruption policy, but often you have to have a power outage of so long before that kicks in. There are some critical examples such as aluminium smelters or foundries where you might see solidification. There is also the issue of insurance for another event that might be triggered by space weather, such as electrical failure. The business interruption policy wouldn't distinguish what the cause was.
- What could we learn / are we learning from elsewhere in the world? Especially America, where the attitude to preparedness is very different because of tornadoes, earthquakes, etc. There may be an opportunity to learn and shift the British psyche. For example the San Francisco preparedness website.
- A lot of the reports in the public domain come from a US study done some years ago that was very sensationalist. There needs to be a consistent but realistic message – e.g. the RAEng report – so that everyone sings from same sheet, which is UK focused and gives an accurate picture.
- There was limited awareness of local resilience forums until this process even amongst some specialists – how do you find out who they are / that they exist? There is a national group for community resilience that has not been very active (it got a little overwhelmed with the winter floods). One specialist attending the next meeting of that group will put space weather on the agenda. It's important to think about it now it is on the risk register, and not many people are doing this. Space weather will certainly be appearing on one resilience forum website as a risk, and it wouldn't have if it hadn't been for this process. A lot of the issues of preparedness are general, not specific to space weather. Emergency responders will be going out and identifying vulnerable people, activating community groups etc during an emergency response. They are ready to do it in general, but just need to have properly nuanced plans.
- There is a need for something you can watch – videos, etc. Also a simple form of 'what's going on' – different types of learning styles. But every person who works in a business is a member of the public too.
- Not many people in the room have an emergency 'kit', but that depends what it means (e.g. a single box or bag of stuff versus having necessary items around the house). If a gold standard of kit / preparedness is advocated, then the expectation is that most people won't reach that. Also there are opportunities for innovative communication such as a themed Ready Steady Cook.
- One thing that might impact on the level of preparedness is how big an area it would impact – e.g. if it is 10 square miles you can go outside of that and visit someone if you are mobile, and it is easier to come in and help vulnerable people. So how big an area gets affected makes a difference, and it's difficult to get a feel for what that might be. Knowing which types of areas and how big they are might be useful for planners.

Levels of preparedness – notes from table 1 (as written)

- Impact would be greater over a wider area than loss of power/communication due to storms etc. Space weather could potentially have international impacts.
- Sectors are building up preparedness but is quite immature – aside from National Grid.
- Can we learn/are we learning from elsewhere in the world especially USA. How can we introduce that kind of preparedness culture here?
- Staying put and not moving around is often the right thing to do – at least in the first instance.
- Are there timescale thresholds about how people react and prepare – stocking of supermarkets to ensure they don't run out of stocks because of panic buying. The Met Office provides weather services to supermarkets – could space weather information be included.
- The role of local resilience forums.

Levels of preparedness – notes from table 2 (as written)

- Timescales – now and ongoing. Put flooding/drought/space weather – each time, gentle ongoing [?] – knit it in.
- 24 hours. CME – will happen. Carefully phrase advice when we have the 24 hour warning. People may decide to work at home e.g. in snow – helps [?].
- ½ hour – when know magnitude, orientation when at L1. Businesses and infrastructure. Certain people – nurses, hospital
- Need something you can watch – video, graphs. Simple – "what's going on" graphs.

Levels of preparedness – notes from table 3 (as written)

- Personal: grab bag (review [?])
- Local resilience forum – knew nothing of them except through this work.
- Congestion/traffic management systems fail.
- RAEng report – getting message out. Something specific to UK / common theme. Had the scare stories / here's the real story.
- Get the message across that it's not the whole of the UK – help is not far away.
- Themed 'Ready Steady Cook' – Ainsley Harriot cook a meal based on what you have in your cupboard.
- How long people will need to survive on their own 24-48 hours.

8. Next steps 3 – What new knowledge is needed?

Attendees spent time at their tables discussing the question above in relation to the dialogue outputs. The key points fed back to plenary are described below, followed by full notes from the table groups.

- We went down the route of forecasting and areas of improved forecasting – the spacecraft up there at the moment are very aged and on their last legs. Funding for replacements is difficult as this tends to fall between science and operations.
- Can you predict when a flare or CME will occur and secondly can you get information about the magnetic field of any structure heading towards Earth? These are two things we have almost no knowledge of.
- A truth serum given to all the operators so they would all come together and say 'yes this is a problem' would be great. At the moment no one will stick their necks out and say 'yes it's a problem', as it would be a competitive disadvantage.
- We need to understand the effect on Earth's magnetic field – some satellite, some radar. We want to know which bit of Earth will be affected.
- We don't know the true cost of a severe space weather event so we don't know how much to invest. Effectively there is the need for a business case, but currently there aren't the numbers to put into this.
- There is great scope for improving modelling but we are also sparse on measurements.
- We need more modelling of the degradation of electronic circuitry on the ground. A better understanding of what we expect to see on the ground level – understanding what's going to occur, particularly as electronic circuits get more embedded and deployed. They are not as well understood as they could be. There is also the issue of concurrence e.g. the original and back up systems going down at the same time. Concurrence might set off different behaviour than occurs with natural background radiation.
- A small amount of additional information slotted into the current education programme, specifically in high school, could teach children not only about space weather but also resilience – so perhaps develop information packs schools can use.
- There is a general need for some materials around this so schools and local resilience forums can pick this up. It needs to be accurate and good quality.
- There is a need for knowledge about how to get this information into schools.
- Develop some more in-depth scenarios about what different types of space weather events might look like. It is great we have the forecasting system but the true value of that is in knowing how to react. The Met Office does have a ready made table top scenario, but that's just one – we need multiple scenarios.

New knowledge – notes from table 1 (as written)

- Who should / how should new research be funded. Through research councils. What is the best way to get academic research translated into services – the Met Office already does this with weather/climate so is well placed to deliver it.
- Research into how we should respond.
- Gap in knowledge on non-electrical impacts. This could be privately funded whereas government should fund research and operational forecasting.
- Research into cascade failures – supply chain etc. to gain more complete picture.
- In depth scenarios about what an event might look like, to understand the impacts.

New knowledge – notes from table 2 (as written)

- Awareness. Teaching – in schools. New knowledge in how to put space weather into the curriculum – slotting in the additional information – activities, data. Magnetic field experiments link. E.g. mention space weather in 1st year at high school when they are drawing the magnetic fields of the sun. PSHE – children have 'resilience' stuff re bullying etc. Can add this in. "Pretend you have woken up and your electric, water and GPS have gone." "What happens if you have no access to cash?"
- Systems. More research/studies of ground level, systems, degradation of electronic circuitry . E.g. RAEng report. Glitches often correct themselves, but we need to know more. [By the way, we discussed aviation and decided it doesn't matter if HF is lost over the poles – coming in to land they will have VHF anyway.] Knock on effects one thing affecting another – concurrence planning/modelling. System and backup fail at the same time if they are affected by space weather.
- Economic research. We can't write a business case for new infrastructure/research because there isn't a recent space weather event to give us a cost of the danger/impact.

New knowledge – notes from table 3 (as written)

- Improved forecasting: we don't know when features are going to erupt.
- Spacecraft – funding falls between science and operations. Systems are getting no/little replacement. Instrument of opportunity are best way forward.
- Terrestrial – "Faraday rotation" radiotelescopes.
- What are the minimum requirements for an operational satellite.
- Flare precursors – theories/nothing in practice.

9. Next steps 4 – What are you planning to do as a result of the dialogue?

Attendees spent some time writing down actions or commitments that they would take away as a result of the dialogue outputs, or suggested actions and commitments from others. These are shown below (as written).

Academia

- Think about what is needed for personal resilience and act on it! And find out who my local resilience team are.
- Ensure any of my research done considers the impact for operational space weather forecasting.
- Continue to tap interest of general public to help serve space weather science through citizen science initiatives.
- Work with partners to develop public engagement / (and) citizen science projects.
- Seek funding to develop forecast model at university / funding council level.
- Contact local schools to discuss talks / activities on space weather science including resilience.
- Consider how the findings of the project will strengthen the case for increased space weather enabling research.
- Prepare my emergency box at home!

Communicators

- Consider features about preparedness and social resilience.
- Wait for authoritative UK scenarios [?] report.

Forecasters

- Seek additional funding for: economic study; broader range of engagement / education material; wider industry engagement.
- Enhance the space weather information on Met Office website.
- Improve the ways space weather forecasts/impacts are communicated both to the public and business & industry.

Government

- Talk to community resilience team in CCS to talk about potential avenues for greater cooperation among LRFs in sharing of knowledge and best practice in general and on solar storms in particular.
- Discuss with colleagues the best form of delivery in communicating the risks of solar storms.

- Find better ways to put over messages on what we are doing to the public.
- Use results to inform case for investment in space weather missions.

Insurers
- Continue to raise awareness within Lloyd's and insurance community on space weather. Not taken seriously at present. Intend to raise all risks on National Risk Register with Lloyd's.

Other/unknown
- Oversight Group identify next steps for sharing images.
- Talk to insurers.
- Further work looking at infrastructure vulnerability and resilience.
- Talk to the Met Office and RAL about their forecasting capability and scenario exercise.
- Think beyond globe – and communications between outer space and Earth.

Public
- Do my bit – prepare myself, and pass it on, not rely on technology as much.
- Have cash at home.
- Have a hard copy address book.
- Continue working with local high school to increase awareness / teach about space weather, its impacts and general resilience.
- I would like to have feedback from the dialogue project and share information with others in school and community.
- Put together a pack.
- Talk to family and friends.
- Make a box with water, candles, cards etc. in it. Not just my camping box. And find my local resilience forum.

Research councils
- Ensure final report is circulated to appropriate people within Science Directorate of NERC and to CE.
- Talk to colleagues about pushing toward UK network/group on avionic and ground based systems.
- Discuss how to contribute material to space weather "resource box" to increase public awareness.
- Try to find out how these results will be used by government, and how we might use them to create new funding for research and instrumentation.
- Better to define the framework for what the modelling and infrastructure needs are (based on the appendices).
- STFC + RAL Space community as central point for resources, media, images, stories, etc.
- Sharing internationally with the contacts we have. There are a number of groups that would be very interested to see what we have done in the UK.

Resilience forums
- Include space weather in risks section of website.
- Feature space weather on community resilience campaign literature ("aware and prepared").
- The LRF will be developing a space weather emergency plan.
- Personally – put together household emergency pack.

Sciencewise
- Help to link the resilience work and lift it up a level to make a coherent story and a persuasive case.

10. The way forward

The evaluators gave an overview of their role and next steps as follows. Icaro is evaluating the project, looking at how it has been delivered. The idea of public dialogue has quite a lot of traction. It's about learning from this process for future dialogues, and looking at particular things that have gone well – for example from the venue to the overall objectives. This happens in three ways: listening to what's going on / observing; talking to participants through feedback forms and

online qualitative follow up question; talking to stakeholders who have been involved in the process, which will happen in the next month or so. This includes asking questions such as 'what you have got from the process', 'did it deliver what you thought it would' and 'what will you do as a result'. Meetings will be set up with 15 or so people in late November / early December to ask you what you thought. The evaluation report, available in late January, will outline thoughts on the process, what went well and not so well.

3KQ outlined the next steps as follows:

- An Oversight Group meeting will follow this meeting, in order to discuss the way forward in more detail.
- 3KQ will produce a report of this meeting and the draft final dialogue report (taking into account discussions at this meeting) by mid November.
- 3KQ will amend the final report based on comments from the Oversight Group, with a view to design and publication at the end of November.
- The final report will be circulated to all those who have been involved in the dialogue project and posted on the website.
- The project team and STFC will discuss how to keep members of public involved in the longer term.