Your response

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Question 1: Are there other trends in the space sector (or the broader spectrum environment) that we should monitor and/or take account of in our strategy?	Confidential? – ¥ / N The Met Office welcomes the publication of the Space Spectrum Strategy and agree that the trends identified in the document will drive changes in the sector over the coming years. As the UK's National Meteorological Service and home of the Met Office Hadley Centre for Climate Science and Services, we are very pleased to see the recognition of weather and climate science requirements within the Strategy. The Met Office looks forward to working with Ofcom to ensure that these requirements are met, to support national resilience and the UK's net zero ambitions. As home of the UK's national Space Weather Operations Centre[1], the Met Office also agrees with the growing importance of space weather to the UK and are pleased to see the prioritisation of this area's spectrum requirements within the Strategy. We will continue to work with Ofcom to ensure that the UK can maximise the benefit of investment in space weather monitoring and forecasting capabilities, and increase our resilience to this hazard.
Question 2: Do you agree with the broad areas we have prioritised for our work?	We are pleased that the importance of Earth observation to support weather forecasting and climate science is identified as a priority in this strategy. As these are core areas of Met Office work, we are keen to work with Ofcom to maximise the benefits which spectrum management can deliver through this sector. In addition to the benefits which this area of science can deliver for the UK's net zero ambitions, weather forecasting applications deliver significant social and economic benefits to the UK and internationally on timescales of hours to weeks ahead. These benefits are especially valuable during emergency situations (such as conflict or natural disasters). In addition to saving lives, this contributes to the aims of the Government's 2021 Integrated Review of Security, Defence, Development and Foreign Policy[2]. Protection of the bands used for remote sensing is essential for the delivery of benefits from Earth Observation through both weather and climate science. The Met Office are interested in understanding more about how Ofcom will support the growth of other spectrum users without undermining the benefits currently delivered through the protection of these passive bands. We are also pleased that the importance of spectrum to enable space weather monitoring and forecasting recognised in the Strategy. Many

[1] https://www.metoffice.gov.uk/weather/learn-about/space-weather/met-office-role

[2] https://www.gov.uk/government/publications/global-britain-in-a-competitive-age-the-integrated-review-of-security-defence-development-and-foreign-policy

	spectrum applications (including communications, navigation and Earth observation) are affected by space weather, so this area is one of cross-cutting priority. The Met Office look forward to working with Ofcom to support the international protections required and ensure that the UK is resilient to space weather impacts.
Question 3: Are there other issues and actions that are likely to be important over the next 2 – 4 years?	The ongoing proliferation of satellites operating in low Earth orbit (LEO) and these being operated from an ever growing number of nations (who may have different regulator regimes for such operations) poses questions around appropriate, safe and sustainable use of the LEO orbital domain. This drives a growing need to ensure appropriate international coordination and regulation to assure sensible use of spectrum, including suitable protection for passive sensors.
Question 4: Do you have any evidence on whether specific actions should be a high priority?	Suggested High Priority Actions within Work Area 2 • Ongoing protection of spectrum used for measurements • Climate change monitoring and weather forecasting capabilities (WRC AI 1.12 & 1.14) • ITU Recommendation dealing with EESS sensors <u>Ongoing protection of spectrum used for measurements</u> As outlined in response to Question 2, weather forecasts provide significant social and economic benefits to the UK and beyond on timescales from hours to weeks ahead. The latest Public Weather Service Value for Money Review[3] concluded with high confidence that the benefits of the Public Weather Service are likely to be close to £1.5bn per annum. The review also found that for weather services as a whole, the benefits are likely to exceed £2bn. These services are dependent upon the International Infrastructure of global exchange of data and weather satellites. The ongoing protection used for measurements made by weather satellites is therefore key to maintaining the £2bn of benefits which weather services provide to the UK. The Met Office will continue to work with Ofcom to provide evidence of sensor performance, and the impact of interference on these sensors and thus the services which we provide. <u>Climate change monitoring and weather forecasting capabilities (WRC AI 1.12 & 1.14)</u> Securing suitable protection for additional measurement systems (through WRC AI 1.12 and AI 1.14) will enable further developments in our understanding of the Earth system and predictive capability. Which will enhance the social and economic benefits which weather forecasts deliver to the UK. For example the Ice Cloud Imaging (ICI) mission – part of a suite of missions to be deployed as part of the EUMETSAT Polar System

[3] https://www.metoffice.gov.uk/about-us/what/pws/value

Second Generation (EPS-SG) programme – will make use of multiple frequency bands, including one at 243.2±2.5 GHz which AI 1.14 relates to. This mission will provide measurements of ice cloud properties and snowfall for the benefit of climate monitoring and operational weather forecasting.

ITU Recommendation dealing with EESS sensors

The Met Office, as the UK's representative in EUMETSAT (which the UK is the second largest contributor to) have an extensive understanding of current and future EESS system characteristics. As such we have been supported billions of Euros of investment in the development of instruments currently in orbit and those due to launch over the next 5-10 years. These are expected to deliver returns on this investment over the many decades of their operation. Many of these instruments have minimal on-board RFI interference protection as they were designed and built with the expectation that the frequency bands used by these instruments would continue to benefit from high levels of protection for the decades of planned operation. The Met Office would be keen to work with Ofcom on the action item on ITU recommendations dealing with EESS sensors outlined in paragraph 5.46 of the Strategy.

Suggested High Priority actions in work area 3

- International regulatory framework for space weather

As outlined in response to question 2, vulnerability to space weather will continue to increase as our society becomes more reliant on systems which could be affected by space weather. Analysis from 2018[4] found that even limited power outages from space weather in Europe could cost €9.3 billion, and that €5.6 billion of this could be avoided with improved forecasting. The wider impacts of space weather events further increase the potential economic impact and the latest UK National Security and Risk Assessment estimates that the economic cost to the UK of a severe space weather event would be in the region of £9 billion, a significant portion of which could be mitigated with improved forecasting. Given this vulnerability to severe space weather, it is timely to prioritise an international regulatory framework for space weather and the Met Office look forward to working with Ofcom to ensure that this provides appropriate spectrum access and protection to deliver benefits to the UK and beyond.

Suggested priority Cross-Cutting actions

- Promoting spectrum sharing: Greater use of network licences
- Promoting spectrum sharing: Conditions on satellite downlinks

[4] Eastwood et al (2018) https://doi.org/10.1029/2018SW002003

	As a user of spectrum for a range of applications, the Met Office is supportive of innovations to ensure that this resource is used efficiently. Given the prominence of Earth observation within the strategy, it was surprising to also see spectrum sharing also feature prominently. We hope that the prioritisation of Earth observation within this Strategy will ensure that frequency bands used for passive remote sensing will continue to be protected from interference, and that the promotion of spectrum sharing in other bands can be used to manage increasing spectrum demand while maintaining this protection.
Question 5: Do you have any other issues you wish to comment on?	As noted in response to question 4, given the prominence of Earth observation within the strategy, it was surprising to also see spectrum sharing feature prominently. For example paragraph 5.44 urges against being overly conservative in protection of passive bands. The Met Office support the efficient use of spectrum, so long as this is supported by scientific studies which demonstrate that it can be achieved without unacceptable consequences, especially for the bands used of passive remote sensing which are highly sensitive to radio interference. Studies should also provide assurance that the protection of passive bands is stringent enough to provide suitable protection from users operating in adjacent bands.
Question 6: Are there other issues and actions specifically relating to NGSO communication systems that are likely to be important over the next 2 – 4 years?	Given that NGSOs will be operating at a lower altitude than many of the instruments which used for Earth observation, this would be expected to generate different challenges in terms of interference with EESS satellite applications. The Met Office would be interested in working with Ofcom to understand these challenges and ensure that suitable protections are in place to provide ongoing protection of spectrum used for measurements which underpin climate change monitoring and weather forecasting capabilities.
Question 7: Do you have any evidence on whether specific actions relating to NGSO communication systems should be a high priority?	Suggested High Priority Actions relating to NGSO satellite communication systems • Efficient use, sharing and assurance for NGSO systems Given the potential for rapid growth in the sector and importance of ongoing protection of spectrum used for measurements, it is surprising not to see any consideration of the impact of NGSO spectrum access on EESS usage. The Met Office would be interested to know more about what consideration has been given to the potential impact of such systems on the EESS allocations used for climate change monitoring and weather forecasting capabilities. While technology such as dynamic frequency selection can enable spectrum sharing, the Met Office have found that despite this technology being required in RLAN devices operating in the 5GHz range, we typically have about 45 interference incidents with our weather radar network at any given time. In addition to degrading

	our ability to monitor rainfall across the UK, Ofcom need to investigate instances of non-compliant equipment which takes time and money. We note that any sharing conditions for NGSO communication systems will need to take into account the limitations which the space operating environment places on regulators' ability to investigate non-compliant emissions and require suitable assurance from users regarding the compliance of their equipment.
Question 8: Do you have any other comments relating to NGSO systems?	There may be opportunities for additional Earth and space weather observations from NGSOs (e.g. exploiting the outcomes of the Space Weather Instrumentation, Measurement, Modelling and Risk Programme[5]). This should lead to the availability of low Size, Weight, and Power environmental sensors with known provenance, that provide useful information to inform space weather monitoring and forecasting, alongside information for satellite operators regarding their immediate operating environment and help accurately diagnose the source of satellite anomalies. Such instruments could be flown on shared purpose satellites, without detriment to primary payloads. There may also be further scope to opportunistically gather useful information from observations, such as those currently used for ionospheric total electron content and atmospheric water vapour content diagnosed from GNSS. The Met Office is also aware of the development of cubesat-based radiometer and radar technology, aiming to provide new sources of Earth observation. Such systems could provide useful additional information to support weather and climate science, building on the existing data available from GSO and Polar orbiting missions. We will continue to monitor the development of this technology and can provide subject matter expertise to Ofcom regarding the usability of data from these systems for research, climate monitoring and operational forecasting.

[5] https://www.ralspace.stfc.ac.uk/Pages/SWIMMR.aspx