Commons Science and Technology Committee: inquiry into UK space strategy and UK satellite infrastructure

Written evidence submitted by the Royal Astronomical Society

1. This is the official response from the Royal Astronomical Society (RAS) to the inquiry by the House of Commons Science and Technology Committee into UK space strategy and UK satellite infrastructure.

2. The RAS represents more than 4,000 astronomers and geophysicists, in the UK and around the world, in occupations in academia, industry, education and public engagement, and journalism, as well as others in the wider economy. Our members are described as 'Fellows'.

3. This written evidence was shaped by input from our governing Council, and more generally from RAS Fellows and others in universities and research establishments.

4. We do not believe there are any prejudicial conflicts of interest to declare. For the record, two members of RAS staff, and a number of members of our governing Council, serve in a voluntary capacity on committees supporting the UK Space Agency, the Science and Technology Facilities Council (STFC) and the Natural Environment Research Council. RAS Fellows are also in receipt of grant funding from these bodies, and STFC sponsors the Society's annual conference.

Executive Summary: key points in our evidence

5. **The UK has a strong space science and astronomy research base. This base needs a fair share of the planned growth in investment in science for the UK to realise its ambitions as a space nation.**

6. **The UK should create a national space science programme to leverage existing investment via the European Space Agency (ESA) and allow more UK scientists to take leadership roles in space missions. This programme would also enable the UK to pursue other international partnerships independent of those delivered through ESA membership.**

7. **A strong UK space sector depends on recruitment of the best scientists and engineers, and is augmented by the movement of people between countries. The UK government needs to offer positive messages encouraging immigration, rather than emphasising barriers.**

8. **The space sector remains overwhelming male and among UK nationals, overwhelmingly white, with poor representation of disabled people. The space strategy should include a diversity plan, working with the space and astronomy community to tackle this imbalance and the failure to recruit talented people irrespective of their background.**

9. **Satellite megaconstellations, including the OneWeb system now part-owned by the UK government, are set to transform Low Earth Orbit (LEO), with the potential for serious detriment to, and significant mitigation costs for ground- and space-based optical and radio astronomy. With a satellite network deliberately overflying the entire inhabited world, even observatories in remote sites will no longer escape the effects of light pollution and radio interference.**

10. **As a megaconstellation part-owner, the UK government has a special responsibility to provide international leadership in this area. It should ensure that the design of its OneWeb system minimises harm to astronomy, and work with partners at the UN, and in the G7, to develop international guidelines and regulations to protect this fundamental science.**

11. **Managing a much more populated LEO environment will require a ramping up in capacity of space situational awareness, for example in understanding the positions of satellites at any one time. At present the UK has limited sovereign capability in this area.**

12. **The environmental and cultural value of the night sky itself deserves protection, recognising its importance to humanity as a whole. The RAS calls for this to be remedied in future space policy plans, which should have a broader range of stakeholders than just industry satellite operators.**

13. **Geophysicists represented by the RAS believe they are not well served by the UK Space Agency. The new space strategy should consider how best to support all the areas of science that depend on gathering and analysing date from space.**

What are the prospects for the UK's global position as a space nation, individually and through international partnerships?

14. In the last two decades the UK has built a stronger research base and become an increasingly important space nation. This is a direct result of the deliberate increase in our contribution to the ESA budget, the creation of the UK Space Agency, partnerships fostered by schemes like Europlanet supported by the EU Framework Programmes, and leading roles in major intergovernmental astronomy organisations like the European Southern Observatory (ESO) and the Square Kilometer Array (SKA).

15. At least until recently this combination of a commitment to scientific excellence, government investment and participation made the UK an attractive destination for scientists from across Europe and from further afield. The 2016 RAS Demographics and Research Interests survey[1] found that half of all postdoctoral researchers were from overseas, with two thirds of those from EU countries. (We plan to repeat this

[1] The Demographics and Research Interests of the UK Astronomy and Geophysics Communities 2016 https://ras.ac.uk/sites/default/files/2018-11/Demographics%20and%20Research%20Interests%20of%20the%20UK%20Astronomy%20and%20Geophysics%20FINAL%20V1.4%2019-10-2017.pdf

survey later this year, to assess the workforce after the impact of Brexit and the Covid-19 pandemic.)

16. Space science and astronomy have also seen a significant increase in the size of their workforces. The RAS survey assessed these to be a total of 1669 full-time equivalent staff, and the 2020 Space Census[2] estimates the wider total space academic headcount at 7,000-10,000, broadened to include areas like engineering. This sizeable cohort is well placed to take advantage of new investment and to help deliver the ambition of the government for the UK to become a 'global science superpower'.

17. For international partnerships, at present almost all of these are via the European Space Agency (ESA) and through this route, NASA. Establishing additional routes requires independent funding, for example for small explorer class space missions not favoured by ESA. This would allow innovative UK led space missions, demonstrating UK technology and boosting both UK space research and business.

18. The UK also has no national space science programme, unlike countries such as France and Germany, which also have ESA subscriptions. This means that they are able to back up their ESA investment with the funds to build instruments for ESA missions, which means they more easily secure scientific leadership through principal investigator roles. UK universities produce world leading scientists and ideas, but without the funding to back this up, many of them move elsewhere, meaning that the implementation of the ideas (and the eventual credit for the results) moves to other nations.

19. The development of the UK as a space nation also depends on ensuring the continued international exchange of people between ourselves and our partner countries. Government policy on this has been inconsistent; on the one hand creating new post-Brexit visas to enable migration, and on the other operating a 'hostile environment' immigration policy with reports of job applicants being placed in detention, for example[3]. The impact of the latter may not emerge until the Covid-19 pandemic ebbs, but will not make it easier to persuade scientists and their families to relocate here.

20. The UK government webpage on working in the UK simply points applicants to restrictions, and the bureaucracy and fees required for visa applications. In contrast the official government website for New Zealand describes reasons for moving there and gives the impression of a country that genuinely welcomes migrants[4]. If the UK government is serious about encouraging scientists and engineers to move here, then it should start a similarly positive campaign, including on official immigration websites.

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[2] 2020 Space Census https://census.spaceskills.org/

[3] "EU citizens arriving in UK being locked up and expelled", Guardian, 13 May 2021 https://www.theguardian.com/politics/2021/may/13/eu-citizens-arriving-in-uk-being-locked-up-and-expelled

[4] Work in New Zealand https://www.immigration.govt.nz/new-zealand-visas/options/work

21. A final comment on the prospects for UK space activity is on the online profile of the UK Space Agency. Unlike its counterparts in other countries, the UK website[5] is subsumed within 'gov.uk', reducing its visibility with the public, media, academic community and industry alike. If space really is to be a key part of a government programme for science and industry, then giving the UK Space Agency a stronger identity would be helpful.

What are the strengths and weaknesses of the current UK space sector and research and research and innovation base?

22. The public policy landscape for science has seen significant change in recent years, for example through Brexit, the medium-term commitment to raise UK investment in R&D to 2.4% of GDP, and ministerial commitment to national challenges and specific scientific projects.

23. Space science, the area particularly relevant to the RAS and to this inquiry, remains strong. The UK is ranked fourth in the world in citation indices for scientific papers in this discipline[6], down from third place since 2013. Astronomy is also productive, and is ranked third in the world on the same metric, though in several years in the early 2000s we were ranked second[7].

24. Our scientists and engineers play a key role in many international space missions. High profile examples include the landing of the Philae probe on comet Churyumov-Gerasimenko, the Herschel infrared observatory, the BepiColombo mission now heading to Mercury, the JUICE mission set to arrive at Jupiter at the end of this decade, the James Webb Space Telescope (JWST) due to launch this autumn, the Euclid telescope exploring dark matter and dark energy, and the ARIEL, CHEOPS and PLATO missions searching for and characterising planets around other stars. Instruments for JWST, the most ambitious space observatory ever built and due to launch this autumn, were built at sites including the Astronomy Technology Centre in Edinburgh and the Rutherford Appleton Laboratory. UK scientists were also instrumental in the reported detection of the biomarker phosphine in the atmosphere of Venus[8], leading to renewed international interest in and now plans for four space probes to travel to our neighbouring planet supported by ESA, NASA and the private company Rocketlab.

25. These inspiring, cutting edge projects result in significant dividends for UK science, public engagement in space and science, and industrial opportunities with companies like EADS Airbus, Cranfield Precision Engineering and EDS Engineering supporting JWST[9], for example.

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[5] UK Space Agency https://www.gov.uk/government/organisations/uk-space-agency
[6] Scimago Journal & Country Rank: Space and Planetary Science https://www.scimagojr.com/countryrank.php?category=1912&area=1900&year=2020
[7] Scimago Journal & Country Rank: Astronomy and Astrophysics https://www.scimagojr.com/countryrank.php?area=3100&year=2020&category=3103
[8] Royal Astronomical Society: Hints of Life on Venus https://ras.ac.uk/news-and-press/news/hints-life-venus
[9] JWST Partners and Contributors https://www.jwst.nasa.gov/content/meetTheTeam/team.html

26. Set against these successes are a number of challenges, including the absence of long-term funding described later in this submission. There is also uncertainty around the precise scope of exclusion of the UK from some Horizon Europe programmes covering space, with details still not public despite a reported agreement between the European Commission and EU27 member states[10].

27. Post-Brexit, UK space scientists and engineers have no access (beyond leaked media reports) to information on whether they will be able to take advantage of pan-European funding and to join and lead partnerships across the continent. Outside of the EU, the UK no longer shapes this programme and we depend on the goodwill of EU27 member states, complicated by other disputes outside of the scientific arena.

28. The interface between the EU and ESA also remains important to the space sector. A high profile example of this was the end of UK access to the Galileo satellite navigation system and to the European Geostationary Navigation Overlay Service (EGNOS)[11] both resulting from Brexit. The other components of the EU Space Programme remain crucial for UK science, not least the ESA Copernicus satellites for Earth Observation, and we look forward to confirmation that the UK will continue its participation.

What should be the aims and focus of a new UK Space Strategy, including considerations of:

- *Skills and diversity*

29. The UK space sector does not reflect the diversity of society as a whole, particularly in the areas of sex, ethnicity and disability, most notably in senior roles. This was noted in the results of the 2020 Space Census and the RAS Survey of Demographics and Research Interests.

30. Data in the Space Census suggest that women are significantly under-represented across the space sector, making up 29% of the workforce, and in industry only 22% of employees.

31. In the RAS Survey 25.5% of research staff (postdocs and similar roles) in astronomy were women and 29.2% of those in solar system science. Among permanent academic staff, women made up 17.3% of employees in astronomy and 23% of employees in solar system science. 11.6% of astronomy professors and 21.2% of solar system science professors were women.

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[10] White smoke? EU deal over quantum, space research lets Horizon Europe proceed https://sciencebusiness.net/framework-programmes/news/white-smoke-eu-deal-over-quantum-space-research-lets-horizon-europe

[11] UK Involvement in the EU Space Programme https://www.gov.uk/guidance/uk-involvement-in-the-eu-space-programme

32. RAS data suggest a slow improvement in the representation of women in permanent roles over time, rising by around 4% for both astronomy and solar system science from 2010 to 2016. The proportion in research posts however changed only slightly in that period, from 25.7% to 25.5% in astronomy and from 27.6% to 29.2% in solar system science. The same survey notes that space science and astronomy have historically been better at recruiting women than physics as a whole, and have seen growth in female representation. The rate of increase may now have slowed, and the RAS and other organisations need to obtain an updated dataset to assess this, but in any case the sector remains far from gender parity.

33. On ethnicity, the Space Census notes that the space sector is slightly less diverse than the UK as a whole (89% of the workforce is white, compared with 86% of the population). The international recruitment of space employers skews this to an extent, with for example half of black employees and a third of Asian employees coming from outside the UK.

34. This is reflected in the RAS survey, where 88% of respondents in academia were white. Among British respondents, 95% were white, again meaning that the diversity visible in universities is a result of recruitment from overseas. Together these surveys suggest that the space sector is failing to recruit employees from British nationals in minority ethnic groups.

35. Disabled people are also under-represented in the space sector. The Space Census states that 8% of sector employees are disabled, compared with 13% of the UK workforce and 16% of the working age population.

36. In the RAS survey, just 2% of both postgraduate students and employees indicated they were disabled. Separate UCAS data suggest that 7-10% of students on undergraduate courses in astronomy and geophysics are disabled. It is hard to say how many disabled undergraduates choose not to pursue postgraduate study and careers in the space sector, but irrespective of the attrition rate (which in academia seems significant) disabled people are significantly underrepresented.

37. The UK Space Agency and its industry partners supported the Space Census, which was a welcome data gathering exercise. There is now a need for a diversity action plan to tackle the enduring underrepresentation of particular groups of people the census reveals, something that the RAS and the community we represent would be happy to collaborate with.

38. On skills, space and astronomy are widely recognised as a 'STEM attractor' encouraging young people in particular to pursue further study and careers in science and engineering in general, exemplified by the European Space Education Resource Office in STEM Learning in York[12]. A vibrant space science programme is key to this, inspiring schoolteachers and students alike and demonstrating the

[12] European Space Education Resource Office https://www.stem.org.uk/esero

possibilities for careers in space in the UK. (The RAS offers resources showing the range of careers possible from initial study of space and astronomy[13].)

- *Research funding, investment and economic growth*

39. The UK government commitment to a total R&D spend (from the public and private sectors) of 2.4% of GDP is welcome, as this is predicated on a significant uplift in public investment in science. However, it remains unclear whether this will result in concomitant increases in investment in fundamental research, including in space and astronomy. Bodies like STFC are still struggling to manage a budget that declined in real terms for more than a decade, and has only recently has seen inflationary rises.

40. Budget increases have instead been concentrated in specific areas, like the Global Challenges Research Fund (itself now subject to cuts in Official Development Assistance) and targeted schemes for industry. Academics have proved adaptable and took advantage of these resources where possible (for example the Development for Africa through Radio Astronomy Project, which involved many UK universities[14]) but the top down constraints in these schemes meant they were no substitute for the desperately needed restoration of core grant funding, and there are in any case no longer any schemes supporting astronomy.

41. Recent one year spending reviews contribute additional uncertainty to the funding landscape, preventing research councils and the UK Space Agency from making the long-term commitments needed to support the development, operation and exploitation of space missions. In 2021 this was particularly stark, as the Agency received a very late budget settlement, compromising support for staff in receipt of grant funding in universities, and damaging the reputation of the UK with our international peers.

42. Growth in the space sector will thus be enabled by stable multi-year funding, longer spending review periods, investment in core research programmes, and a long term financial commitment to projects like space science missions.

- *Industry*

43. UK industry accrues significant benefits from research in space science, ranging from direct instrument building to spin-out technologies and development of skilled personnel. The RAS regularly documents these examples based on input from our Fellows and by analysing documents submitted to the Research Excellence Framework[15].

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[13] Careers Booklet: Sky High and Down to Earth https://ras.ac.uk/education-and-careers/careers-booklet-sky-high-and-down-earth

[14] Promoting STEM skills and economic development through radio astronomy https://www.newton-gcrf.org/impact/stories-of-change/promoting-stem-skills-and-economic-development-through-radio-astronomy/

[15] RAS: Impact and Industry https://ras.ac.uk/ras-policy/impact-and-industry

- *International considerations and partnerships*

44. As noted above, the UK space sector has benefited enormously from membership of EU Framework Programmes. In astronomy and space science in academia, UK institutions received significant funding from the European Research Council[16] (amounting to an estimated 30% of grant resource in a typical year) and the Marie Sklodowska-Curie Actions scheme. The strength of the sector depends on these and other formal relationships with international partners like ESA and NASA, and the RAS would welcome a commitment to develop additional agreements with other spacefaring nations.

- *Impacts of low Earth orbit satellites on research activities*

45. At the start of 2019 there were around 2,000 satellites in Low Earth Orbit (LEO), the region of space up to an altitude of 2,000 km. In June of that year SpaceX began its deployment of the first satellite 'megaconstellation', Starlink, and planned launches from this and other companies may see more than 100,000 satellites in LEO by the end of this decade.

46. This is a scale of change not seen since the beginning of the space age, and one that largely took the astronomical community by surprise. At the time of the first SpaceX launch the major global astronomical organisations (including the RAS[17], the American Astronomical Society[18] and the International Astronomical Union[19]) all issued statements of concern about the impact of these deployments on the operation of and results from radio and optical telescopes, and on the general appearance of the night sky.

47. Satellites are visible through reflected sunlight, with their brightness dependent on their size, altitude and their composition and design. They are fast moving, so cross through the field-of-view of astronomical telescopes (with exposure times ranging from tens of seconds to hours) and appear as bright streaks across images. Initially SpaceX satellites were bright enough to attract public attention and were easily visible to the unaided eye as so-called 'strings of pearls'[20].

48. Satellites also receive and send signals to Earth to transmit data, or in the case of the proposed megaconstellations, to carry Internet traffic. These signals interfere with the work of sensitive radio observatories, and are vastly – 10 trillion times - more powerful than the faintest emissions detected from astronomical sources.

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[16] In 2020 alone UK researchers in astronomy and space science were awarded €17.7 million in ERC grants https://erc.europa.eu/projects-figures/project-database
[17] RAS Statement on Starlink satellite constellation https://ras.ac.uk/news-and-press/news/ras-statement-starlink-satellite-constellation
[18] AAS Issues Position Statement on Satellite Constellations https://aas.org/press/aas-issues-position-statement-satellite-constellations
[19] IAU Statement on Satellite Constellations https://www.iau.org/news/announcements/detail/ann19035/
[20] Wow! This Is What SpaceX's Starlink Satellites Look Like in the Night Sky https://www.space.com/spacex-starlink-satellites-spotted-night-sky-video.html

49. The impacts on astronomical research include rendering some data from optical telescopes unusable. In particular, survey instruments like the new Vera Rubin Observatory (VRO), in which the UK is a key partner, could lose 30-40% of their images, while the European Extremely Large Telescope (E-ELT) will see up to 3% of frames affected in the same way[21]. Megaconstellations will also impact on space-based observatories in LEO, and for example the Hubble Space Telescope already sees streaks from satellites in 5% of its images.

50. At radio wavelengths the harm could be more severe, and for example the SKA, under construction in southern Africa and Australia, could see its work badly compromised[22]. SKA HQ is at Jodrell Bank in Cheshire, and as a leading member the UK has made significant investment in this project. Only a very small fraction of the radio spectrum (below a frequency of 15 GHz) is fully protected for radio astronomy by the International Telecommunications Union (ITU), and most of the high-impact science projects require observations outside of these narrow protected bands.

51. The new satellites will transmit at frequencies between 10.7 and 12.7 GHz, adjacent to a narrow protected radio astronomy band at 10.68-10.7 GHz, for example. There are concerns about leakage into this protected band, even at a low level, but also about the impact on the ability of astronomers to observe across this unprotected wider band, which is key for SKA. Jodrell Bank is also currently proposing to equip the e-MERLIN array, which has 7 telescopes spanning 210km from Cambridge to Shropshire, at this frequency.

52. Until now radio astronomers relied on local protection of observatories from interference and / or by constructing telescopes in remote sites far from artificial radio signals. By definition a constellation of satellites intended to provide global coverage will fly over the whole inhabited world, so geographical location alone will no longer be sufficient to escape interference.

53. Simulations of the specific impact on different radio telescopes and arrays are underway. In the UK, Jodrell Bank is developing software which will simulate the aggregated impact for entire constellations across the whole sky based on models of the transmit (satellite) and receive (telescope) beams. An extension of this software will assess the impact on interferometric arrays which combine signals from multiple antennas in order to produce high resolution images. The simulations will indicate the extent of the impact on the e-MERLIN and European telescope networks in which the UK also participates.

54. Some specific areas of work in astronomy are much harder to mitigate, as they are based on observations of phenomena that do not repeat. These include 'fast transients', where a source rapidly brightens and fades, in some cases of unknown

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[21] "On the Impact of Satellite Constellations on Astronomical Observations with ESO telescopes in the Visible and Infrared Domains", Hainault O. R. and Williams A. P., Astronomy and Astrophysics, March 2020 https://arxiv.org/abs/2003.01992

[22] See the comment from SKA on the impact on its work https://www.skatelescope.org/news/skao-satellite-impact-analysis/

origin; detection of near-Earth objects in surveys; and the temporary visible light counterparts to gravitational wave events that result from dramatic phenomena such as the merger of black holes. All of these are areas with significant UK research expertise and involvement.

55. The global astronomy community more generally is carrying out a substantial amount of work on assessing the impact of the new constellations, working with SpaceX in particular on modifications to satellite design, and pursuing political engagement in the US, UK, Europe and at the United Nations. (The RAS convenes meetings of representatives from the UK astronomical community and with both SpaceX and OneWeb.)

56. One initial output is the IAU "Dark and Quiet Skies for Science and Society"[23] (D&QS) report for consideration by the UN Committee on the Peaceful Uses of Outer Space (COPUOS), modified on the basis of feedback in discussions at a virtual conference last autumn.

57. D&QS recommendations cover mitigation or removal of the effects of satellite constellations, and are designed for astronomers, satellite operators and international policymakers. The IAU submitted it to the COPUOS Scientific and Technical Subcommittee at the start of this year for consideration by member states.

58. Recommendations in the report, which the RAS supports, include reducing the light reflected by satellites (SpaceX have initiated this with the DarkSat and VisorSat designs, though not yet to the level required[24]); reducing the deployment altitude for satellites to a maximum of 600 km; directing radio signals to avoid radio observatory sites; deploying the minimum number of satellites required for operations; ensuring that satellites spend as little time as possible away from deployment altitude (i.e. after launch and before deorbiting); and providing positional information to astronomical observatories.

59. At the most recent COPUOS meeting the UK took a neutral position, and would not endorse the D&QS report in the first instance. After objections to the report from countries including Russia and China, it will now return for discussion in 2022, delaying the development of internationally recognised guidance on good practice for LEO satellites. We urge the UK government to take a stronger line next year, and to back the IAU recommendations to protect astronomy, as an area of science where we are world-leading.

60. Science and Technology Committee members should note that licensing of satellite systems is surprisingly unregulated at a global level. Operators make requests to national regulatory bodies, such as OfCom in the UK and the Federal Communications Commission (FCC) in the US, who authorise operations. These

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[23] Dark and Quiet Skies for Science and Society https://www.iau.org/static/publications/dqskies-book-29-12-20.pdf

[24] "The Brightness of VisorSat-Design Starlink Satellites", Mallama A., January 2021 https://arxiv.org/pdf/2101.00374.pdf

report into the ITU, which maintains an international record of satellite systems. The Artemis Accords, to which the UK is a signatory, continue the plan for regulation of space activities by individual states[25].

61. Alongside this Article IX of the Outer Space Treaty, dating from 1967, places an obligation on signatories to ensure that their activities are carried out without 'harmful interference' to the 'peaceful use and exploration of outer space' and that consultation should be carried out with affected parties, but this has so far not been seen to apply to the interests of astronomers[26].

62. OneWeb, with SpaceX one of only two megaconstellation operators with satellites already in orbit, is now part-owned by the UK government, though its spacecraft are licensed through the FCC. This ownership gives the UK a global responsibility and is an opportunity to demonstrate good practice in respecting the interests of satellite operators, the scientific community and the population as a whole.

63. RAS staff and Fellows have met with officials from the UK Space Agency and BEIS to discuss OneWeb. This conversation is at an early stage, and we would like as a minimum to see a commitment for future satellite design and deployment to meet the D&QS proposals. (OneWeb satellites are notably deployed at a much higher altitude (1200 km) than Starlink (500 km), meaning they will be in sunlight for much longer in each orbit and are visible throughout the night during the summer months.) Radio astronomers report difficulty in engaging with OfCom on this issue, and its practical remit appears inadequate for managing the full ramifications of deployment of large constellations of satellites, and considering the variety of stakeholders affected. There is also no mention of the impact on optical astronomy in its guidance for filing requests[27].

64. Some astronomers now call for a moratorium on the deployment of satellite megaconstellations until the 'space environment' issues are resolved, though even if the UK adopted this proposal it seems unlikely that the many other nations with plans for constellations would agree to do the same. The recent G7 summit agreed the 'safe and sustainable use of space' in a welcome commitment to tackling space debris and ensuring good space traffic management[28], but the absence of any mention of the scientific impacts of large scale satellite deployment was a missed opportunity.

65. Managing megaconstellations (and space debris and space weather) also requires systems for space situational awareness, for example of the positions of satellites at

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[25] THE ARTEMIS ACCORDS PRINCIPLES FOR COOPERATION IN THE CIVIL EXPLORATION AND USE OF THE MOON, MARS, COMETS, AND ASTEROIDS FOR PEACEFUL PURPOSES https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf

[26] UNITED NATIONS TREATIES AND PRINCIPLES ON OUTER SPACE https://www.unoosa.org/pdf/publications/STSPACE11E.pdf

[27] OfCom Procedures for the Management of New Satellite Filings https://www.ofcom.org.uk/__data/assets/pdf_file/0022/140926/new-procedures-1.pdf

[28] "G7 nations commit to the safe and sustainable use of space" https://www.gov.uk/government/news/g7-nations-commit-to-the-safe-and-sustainable-use-of-space

any time. In the early days of the space age, Jodrell Bank made pioneering contributions to this area. The UK now though has little in the way of dedicated sovereign capability in this area, particularly with radar facilities, other than Fylingdales in Yorkshire, so is working with teams in Germany and the US[29]. There are now some efforts to restart the UK programme with the Defence Science and Technology Laboratory and others to work on passive and active satellite measurements, something which needs to be ramped up to handle the growth in use of LEO we will see over the next decade.

66. There are techniques in software and in the way data is collected that mitigate interference from satellites to some extent. Implementing these adds a cost burden to the scientists and engineers operating facilities, and to astronomers processing data. The UK government should consider the tension between its investment in a megaconstellation system (a £400m purchase), and the investment in existing and new astronomical facilities that will accrue additional overheads as a result. UK investment in SKA is £270m for the first decade, in ESO amounts to £380m, while £20m (plus £20m in-kind) is going to the Vera Rubin Observatory, and £2.5m each year to the e-MERLIN radio observatory.

67. The large number of amateur astronomers around the world is another affected group, as is the wider public. In the UK alone the Society for Popular Astronomy and the British Astronomical Association have at least 5,000 members between them, there are 199 local groups affiliated to the Federation of Astronomical Societies and the RAS itself has around 1,000 'advanced amateurs' in its membership.

68. There has so far been little discussion of the impact on this group in policy debates, nor of the wider 'ownership' of the sky and its place in our culture, as part of a 'global commons'[30]. Groups like the countryside charity CPRE also see access to a dark night sky as worthy of environmental protection, something also not considered in official consultations on UK space activities. We therefore call for this to be remedied in future space policy plans, which should have a broader range of stakeholders than just industry satellite operators.

What needs to be done to ensure the UK has appropriate, resilient and future-proofed space and satellite infrastructure for applications including:

- *Navigation systems*

69. Space-based navigation systems depend on highly accurate measurements of the shape of the Earth, or geodesy. A key technique for this is Very-Long Baseline Interferometry (VLBI), where radio telescopes at widely separated terrestrial locations use distant astronomical sources to determine the Earth's orientation in

[29] NATO: RF Sensing for Space Situational Awareness https://www.sto.nato.int/Lists/test1/activitydetails.aspx?ID=16824

[30] See e.g. "The impact of satellite constellations on space as an ancestral global commons", Venkatesan A., Lowenthal J., Prem P. and Vidaurri M., Nature Astronomy, November 2020 https://www.nature.com/articles/s41550-020-01238-3

space. The operation of these telescopes for astronomy, unimpeded by the satellite constellations under construction, is thus essential for navigation underpinning a large amount of activity in modern society.[31]

- *Earth observation including climate change*

70. Solid-Earth geophysicists, also represented by the RAS, depend on data from space for insights into the nature of our planet. A good example is the ESA Swarm[32] mission launched in 2013. Outputs from this include the World Magnetic Model[33], used in civilian and military systems, and the British Geological Survey (BGS) Global Geomagnetic Model[34], used for directional drilling in the oil and gas industry. Magnetic field models are also essential for fundamental research into how the Earth's magnetic field is generated, and space weather.

71. UK scientists have the technical ability to develop both small satellites and magnetometers to provide missions to follow on from Swarm, an area that could be considered for government support in the future space strategy.

72. In the overall area of geomagnetic field research and space weather the UK both contributes to and benefits from its ESA subscription. One geophysicist RAS Fellow notes though that the UK Space Agency 'has shown very little interest' in supporting research based on data from low-Earth orbit satellites. The Agency should investigate this and consider how it engages with the research community across scientific disciplines, something that could also be formally included in the new space strategy.

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[31] Space Geodesy Project: What is VLBI? https://space-geodesy.nasa.gov/techniques/VLBI.html
[32] SWARM: Earth online https://earth.esa.int/eogateway/missions/swarm#:~:text=Swarm%20is%20ESA's%20first%20constellation,into%20a%20near%2Dpolar%20orbit.&text=Swarm%20was%20designed%20to%20operate,a%20three%2Dmonth%20commissioning%20phase
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