Review of the BBC's Research & Development Activity

January 2018

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1. Executive Summary

This report fulfils the BBC's commitment to review its research and development activity

1. Research and development has been an integral part of the BBC's public service contribution over the past 90 years. Some of the most significant advances in broadcast technology began in the BBC's R&D department, including noise-cancelling microphones in the 1930s, the first transatlantic television transmission in the 1950s, Ceefax in the 1970s, digital radio in the 1990s and digital TV in the 2000s. The department was the driving force behind the BBC's pioneering move online in the mid 1990s.

2. As technology continues to develop, the start of the BBC's new 11-year Charter represents an appropriate moment for reflection, and provides an opportunity to assess R&D's impact and consider objectives for the future.

3. In the December 2016 Framework Agreement, the BBC undertook to review its R&D activity, including:

    a. A cost-benefit analysis (which includes an analysis of the value delivered for the public and the creative and wider economy)

    b. A qualitative assessment of the success achieved as a result of the investment in research and development activity taking into consideration at least the previous Charter period, and up to the date of the review; and

    c. Consideration of objectives for the future, and potential ways in which the BBC may be able to improve collaboration with others.

4. This report contains the findings of that review, which included three analyses: an independent assessment by DotEcon of the costs and benefits of BBC R&D activities (published separately alongside this review); an internal qualitative assessment of the impact of R&D activity over the 2007-16 Charter period; and a review of objectives for the future and opportunities to improve collaboration, drawing on interviews with senior leaders across the BBC.

5. Overall, we find that the BBC's R&D activity over the Charter period delivered substantial value to audiences, the UK creative sector and the economy as a whole. It will remain an essential and distinctive aspect of the BBC's public service activities in the 2017-27 Charter. But changing market and technological conditions will require the BBC to continue to evolve its focus and partnership models.

Four drivers for R&D activity

6. Our review has identified four motivations for the BBC's R&D activity.

7. First and foremost, R&D can deliver value to audiences and society, aligned with the BBC's public purposes. It innovates for universal benefit, for example developing Internet streaming technologies and TV platforms that have made the opportunities of connected

media as widely available and taken up as possible, while also ensuring that public service broadcasting remains prominent and easy to access. It played a major role in ensuring that no home was left behind during digital switchover. It invests in technologies that deliver new forms of public value and for which a commercial model may not exist – examples in the 2007-16 Charter period include the BBC micro:bit coding platform and research into subtitle speeds.

8. Secondly, R&D can give the creative community (inside and outside the BBC) the tools it needs to fulfil the purposes of public service media by delivering exceptional and distinctive content to audiences. Early innovations in emerging technologies pave the way for later mass-audience deployments that can transform the value the BBC, and other broadcasters, delivers to audiences.

9. Thirdly, R&D can support cost-effectiveness and value for money, by cutting costs, avoiding future costs, making innovation affordable by creating efficient ways to do new things, or by creating assets capable of commercial exploitation. In meeting this goal it is necessary to balance the potential commercial value of exploitation of proprietary intellectual property with the public value of making new technologies widely and cheaply available.

10. Finally, R&D can achieve these goals in such a way that it delivers value to the wider industry and the UK, by opening up the benefits of innovation to other organisations, supporting and driving pan-industry collaboration and acting as an ambassador for the UK in an increasingly global media sector. It creates routes to market for new businesses and talent, through open innovation initiatives like BBC Backstage, Taster, News Labs and Connected Studio.

11. Successful initiatives will generally serve more than one goal. For example, innovations in Object-Based Media (OBM), which exploits the interactive potential of online video and text to deliver audiences more personalised, immersive, flexible and reusable content, will add creative value to audiences as well as generating savings.

12. Government has given the BBC specific direction with respect to R&D activity. In the 2007-16 Charter, the BBC's sixth public purpose was "helping to deliver to the public the benefit of emerging communications technologies and services, and, in addition, taking a leading role in the switchover to digital television." The current 2017-27 Charter specifies that "the BBC must promote technological innovation, and maintain a leading role in research and development, that supports the effective fulfilment of its Mission and the promotion of the Public Purposes," and in doing so must "focus on technological innovation to support the delivery of the UK Public Services, non-service activities and the World Service, seek to work in partnership with other organisations, and share, as far as is reasonable, its research and development knowledge and technologies."[1] Under the terms of the December 2016 Framework Agreement, the BBC committed to conduct R&D activities which "aim to maintain the BBC's leading role in research and development in broadcasting and other

[1] Royal Charter for the Continuance of the British Broadcasting Corporation ('BBC Charter'), Dec 2016, s15

means for the distribution and consumption of audio, visual and audiovisual material and other content, and in related technologies."[2]

Our evaluation found significant benefits, for audiences, the creative community, the wider industry and the UK economy, from R&D activity in the 2007-16 Charter

13. Over the last decade, the BBC spent £161m on R&D activity. It currently employs c. 205 people, based in research laboratories in Salford and London. It forms part of the BBC's Design & Engineering division, whose objectives are to build a world class technology division, drive the digital transformation of the BBC and be the catalyst for the BBC of the future. R&D plays an active role in all these objectives. Its priorities are also set with reference to the BBC's wider strategic objectives and public purposes.

14. Based on both the internal and external analyses conducted for this review, we have assessed the impact of the BBC's R&D activities in the 2007-16 Charter, with respect to the drivers identified above.

15. For **audiences and society**, R&D enabled the BBC to deliver new types of content, more flexibly, to higher quality standards. Over the Charter period, BBC R&D gave audiences significantly better picture quality, innovative sports graphics, greater accessibility through improved subtitles, a wide range of new creative experiences and enhanced coverage of national events like General Elections, Glastonbury and the Olympics. R&D provided significant investment and technical contribution to Freeview Play, Freesat and YouView, working collaboratively with industry partners. These platforms helped ensure public service broadcasting – whether broadcast or online – remained universally available, prominent and widely used.

16. The **creative community** benefited from R&D's leadership in online innovation, which dates back to the early years of the Internet, in which the BBC played a pioneering role as one of the first large organisations to be online. BBC R&D was the driving force behind introducing the BBC to the Internet and educating the organisation, and the wider UK media sector, about the advantages of Internet technology. Between 2007-16, it continued to set the direction for the BBC's Internet transition; R&D's early work on Internet technologies, and trials of new forms of content delivery such as online streaming, provided know-how for the launch of BBC iPlayer in 2007. The Redux online archive opened up new opportunities for BBC content-makers to experiment with the re-use of historic material. More recently, the BBC has used OBM to create new experiences in news and drama that complement and enrich traditional TV and online output.

17. With respect to **cost-effectiveness and value for money**, the BBC Internet Distribution Infrastructure (BIDI) initiative gave the BBC greater control over online distribution of its content, and will help manage costs in this rapidly growing area. New technologies were developed for commercial exploitation, such as the Piero sports graphics system, launched as a product with Ericsson. The BBC used R&D's patent portfolio both to ensure that where appropriate it can secure the commercial value of its innovations, and also to support the

[2] An Agreement Between Her Majesty's Secretary of State for Culture, Media and Sport and the British Broadcasting Corporation ('BBC Agreement'), Dec 2016, s65

industry in taking up standards and technology for the benefit of all audiences, by ensuring that technology was made available on affordable terms.

18. The **wider industry** benefited from R&D's role in supporting and driving pan-industry collaboration. R&D staff contributed to the development of industry-wide technology solutions (for instance in the development of the AS-11 file specification to help the broadcast industry move from tape-based programme delivery to a common file-based approach). They played a major role in industry forums, for example by chairing World Wide Web Consortium (W3C) working groups, engaging in the 3GPP 5G standards forums, and chairing the Digital Video Broadcasting (DVB) technical subtitling group. And BBC Backstage and Connected Studio enabled hundreds of new developers, storytellers, academics and entrepreneurs to create new types of media experiences and exploit new technical and commercial opportunities.

19. Over the last few years, the BBC pioneered a move from broadcast industry-specific production architecture to one based on generic Internet technologies. This will reduce the industry's dependence on specialised equipment and make it easier to support flexible workflows, such as remote production. The BBC worked closely with industry throughout, leading several industry bodies to develop the architecture, and a collaborative working group, the Networked Media Incubator, to develop, test and standardise Internet Protocol (IP) production standards. The technology is now sufficiently mature that industry is adopting it at scale, and an industry body has formed with members including Sony, Cisco, NBC Universal as well as other important members like Grass Valley and Snell Advanced Media, to promote solutions compatible with these standards.

20. The UK as a whole derived economic value from this activity. DotEcon's independent quantitative analysis finds net economic benefit of between £5-9 for every pound spent by BBC R&D over the 2007-16 Charter period. This is based on a weighted average cost-benefit ratio of case studies, aggregated to the department as a whole. This estimate does not account for all future benefits and assumes smaller projects do not generate any benefits, and as such we believe is conservative. The report concludes that there are direct benefits to BBC viewers and listeners, direct financial benefits to the BBC (cost savings and licensing revenues), indirect benefits to the BBC (such as the value to audiences of time spent with BBC services) and spillover benefits to the wider broadcast and audiovisual sectors.

21. Some projects have delivered significantly greater return. For example, DotEcon estimates that the Piero system has delivered £46-77m of benefits to date, for a cost of just over £1m.

22. DotEcon cites several benchmarks that show similar cost-benefit ratios from research and development programmes, including InnovateUK's 'Smart' R&D financing programme (cost-benefit ratio of between 1:4 – 1:5); the Technology Strategy Board's Collaborative Research and Development programme (£6.71 benefit for every pound spent); and the EU Horizon2020 programme that expects to deliver benefits of €6-8 for every Euro invested.

As the pace of innovation quickens, R&D's role will remain vital, but must adapt to changing market and technological conditions

23. R&D will need to continue to evolve to maintain its distinctive value and impact in the 2017-27 Charter. Looking ahead, the media and technology sectors will become more global and more complex, and the pace of change will continue unabated. As audience behaviour and consumption patterns develop, new technologies, markets, competitors and partners will need to be addressed; there is a risk of reliance on tried-and-trusted relationships and familiar technologies. The market will deliver a great deal of innovation, and R&D must work out carefully where it can best leverage its capability and where its involvement is essential to delivering public value.

24. Three areas stand out as particularly significant. Firstly, evolving Internet and mobile standards will shape the media ecosystem and determine the future of media distribution – the effectiveness of R&D's participation in industry groups and its engagement with the wider sector will be more important than ever. Secondly, the shift from bespoke industry-specific technologies to generic IP-based approaches in content production will open up fresh creative opportunities. Thirdly, new approaches to content production and distribution will drive creative innovation, enabling new content and storytelling formats. R&D has worked with partners to play a major role in these developments; it must now help the BBC, and the UK's wider creative community, adapt to and exploit the new possibilities.

25. So looking ahead, BBC R&D will continue to have a number of vital roles to play. It must help transform the BBC to ensure it fulfils its public purposes while adapting effectively to this changing context. Specifically, it must help prepare the BBC for a smooth transition to Internet delivery, focusing on delivering value for younger audiences, and placing personalisation, participation and partnership at the core of the BBC's services and operating model. It will do this both through leading its own initiatives and partnerships, and also by providing in-house expertise to support BBC creative teams as they explore the possibilities of new technologies.

26. And it must engage internationally, through forums like W3C, 3GPP, ITU, DVB, and the MPEG audio and video compression standards body, to ensure the BBC's commitment to universal free-to-air public service media can be delivered in a new technological environment.

27. R&D's specific objectives for the 2017-27 Charter period take into account these considerations, and are driven by the wider objectives of the BBC. They are to:

    a. Develop new types of content for audiences, taking advantage of Internet and data-driven technologies, and becoming more personal, interactive, immersive, adaptive, dynamic and responsive

    b. Influence the development of the next generation of audiovisual standards and norms, and prepare the BBC for their adoption in order to continuously improve sound and picture quality for audiences in an Internet-driven world

c. Develop and test new forms of public value, anchored in the BBC's public purposes, thereby taking advantage of technology to create experiences for audiences that go above and beyond television, radio and online

d. Develop insights into Internet-led production technologies that enable new types of content, reduce costs and enhance creativity across the global industry

e. Support and improve existing distribution approaches, and prepare the BBC and industry for an Internet-led distribution future that supports the public service mission and ensures that content is capable of being delivered in, and takes advantage of, future distribution and consumption environments

f. Capture and store content, personal and meta data in such a way that it can be efficiently and effectively used in creating new types of content, and create the tools for analysing and using that data

g. Provide the means to create a collaborative ecosystem for producers, content makers and audiences, taking advantage of Internet capabilities

28. As market context, technical capability and audience behaviours continue to change, these objectives will flex to adapt over the next ten years. Given the pace of change, it is appropriate that R&D has discretion to evolve its strategy, objectives and activities. Evolution in R&D's objectives will be managed through existing governance processes, including an annual planning process, regular project reviews, and outcome monitoring.

29. While it is too early to specify in detail exactly what specific initiatives will be required from R&D over the whole of the 2017-27 Charter period, our review of ongoing and planned activities in these areas suggest they are well aligned to the strategic challenges faced by the BBC. They will:

    a. Benefit audiences and society in line with the BBC's public purposes, giving them access to more personal, responsive and shareable experiences, and seeking to bring the benefits of Internet connectivity to all audiences;

    b. Give the creative community the tools they need to deliver the public purposes in an Internet- and mobile-first age, for example with the further development of Object-Based Media, working with partners to create content that is 'aware' of the user and user surroundings and can be repurposed across different channels, enabling multiple experiences to be built from a single content asset;

    c. Enhance the BBC's cost-effectiveness and value for money, for example by managing the BBC's costs of distribution, driving efficiencies in production and rolling out low-cost automated transcription tools; and

    d. Deliver value to industry and the UK, for instance by working with others to build a new technical ecosystem capable of delivering new content types, and based on common standards that make these new formats universally available.

30. R&D must continue to evolve its focus and skills to secure these benefits. While much of its current activity will continue to remain relevant, some areas will change; and some entirely new challenges will need to be addressed, both in the interests of audiences and for the wider benefit of industry. R&D has always worked in partnership, but its future success depends on collaboration with an evolving, and growing, set of organisations. Its partnership models and choice of partners will need to flex accordingly. While it is building on a solid foundation of successful innovation in partnership, R&D will need to adapt its convening, open and public service approach to new challenges.

2. Introduction and context

R&D has contributed to many of the BBC's most significant achievements

31. Research and development has been part of the BBC's DNA from the beginning of the organisation in the 1920s. Its mission and purpose is enshrined in the BBC's most recent Royal Charter and the associated Charter agreement.

32. Over the past nine decades, the BBC's R&D department has been responsible for some of the most significant advances in broadcast technology, delivering significant benefits to audiences, the UK economy and the global broadcasting industry. Examples include noise-cancelling microphones in the 1930s, the first transatlantic television transmission in the 1950s, Ceefax in the 1970s, digital radio in the 1990s and digital TV in the 2000s. Common household brands such as BBC Red Button, BBC iPlayer and the UK's free-to-air platforms Freeview, Freesat and YouView were all launched with significant input from BBC R&D.

33. The department led the BBC in recognising the opportunities of the Internet in its very early days.[3] BBC R&D's work to make the BBC, and the wider broadcasting community, Internet-fit reach back to the mid-1990s when the department was the driving force behind moving the BBC to the Internet and educating the organisation, and wider UK ecosystem, about the advantages of online technology. At a time when few large organisations were going online, the BBC pioneered digital content, ways of working and service innovation. R&D was central to this, including supporting the BBC Networking Club in 1994 – within a few years of the invention of the World Wide Web – which helped non-technical audience members to access the Internet.

34. Now technological development and change are happening faster than ever. The BBC operates in an increasingly global sector. Drivers of innovation include some of the world's biggest and best-funded firms as well as start-ups.

35. So the BBC's approach has evolved. It collaborates with an increasingly wide range of partners, complementing and supporting market innovation. It prioritises distinctive activity consistent with the BBC's public purposes, and that delivers value for money for licence fee payers.

The Government mandate to innovate

36. R&D's ongoing role in the development and propagation of media and communications technologies is not only a matter of choice by the BBC. It has been a core element of the BBC's mandate from Government since the introduction of the public purpose framework in the 2007-16 Charter. One of the BBC's six public purposes in that Charter was:

[3] http://www.bbc.co.uk/programmes/p01xz2d9

"*in promoting its other purposes, helping to deliver to the public the benefit of emerging communications technologies and services and, in addition, taking a leading role in the switchover to digital television*."[4]

37. So the BBC had a specific responsibility to help lead the switchover from analogue to digital broadcasting, but also a wider objective to help make the benefits of Internet- and mobile-centric media available to the public. This did not require the BBC itself to lead the way in new technology, ahead of the market, and in fact it did not do so. It almost always worked with other partners, complementing commercial innovation, rather than working independently.

38. However, fulfilling this mandate required the BBC to retain its own R&D capability to ensure that the needs of its audiences and creative teams were served by technological developments. R&D needed to have the technical expertise and track record to 'earn a seat at the table' in the international forums and working groups that increasingly determine how new technologies develop and are implemented. In return, this secured the BBC's influence over developments and helped ensure that its audiences' interests, and the wider public good, are taken into account.

39. In the 2017-27 Charter, this broad duty is reiterated and expanded. While no longer included in the BBC's public purposes, the Charter specifies that:

"*The BBC must promote technological innovation, and maintain a leading role in research and development, that supports the effective fulfilment of its Mission and the promotion of the Public Purposes. In complying with this article, the BBC must—*
(a) focus on technological innovation to support the delivery of the UK Public Services, non-service activities and the World Service;
(b) seek to work in partnership with other organisations; and
(c) share, as far as is reasonable, its research and development knowledge and technologies."[5]

40. The Agreement provides further detail:

"*The BBC must ensure that it conducts research and development activities geared to the fulfilment of the Mission and the promotion of the Public Purposes and which aim to maintain the BBC's leading role in research and development in broadcasting and other means for the distribution and consumption of audio, visual and audiovisual material and other content, and in related technologies.*

In carrying out [this] function, the BBC must pay particular attention to supporting and engaging actively in national and international forums for the development of "open standards" (that is to say, technologies where opportunities to participate in their creation are made widely available, free of charge or on terms that are fair, reasonable and non-discriminatory).

[4] BBC Charter, October 2006, s4(f)
[5] BBC Charter, December 2016, s15

These activities should be conducted both within the BBC and, as much as possible, in co-operation with suitable partners, such as university departments and businesses which are active in relevant fields of research and development or the practical application of the fruits of such research and development.

The BBC must keep its research and development activities under review, and must (in particular) ensure that an appropriate balance is struck between
(a) the potential for generating revenue through commercial exploitation of its intellectual property, and
(b) the value that might be delivered to the public and the UK economy by making new developments widely and openly available."[6]

41. Having undertaken a comprehensive review of the BBC's remit in the Charter Review period, including consulting on what role the BBC should have in influencing the future technological landscape, the Government has concluded that the BBC must continue to innovate as it has up till now – in support of its purposes, in the interests of its services and creative talent, collaboratively and in ways that secure both commercial benefit and the public value of wide and open availability.

Now is an appropriate time to review the BBC's R&D activity

42. The BBC's new 11-year Charter came into effect on 1 January 2017. The start of a new Charter is a good opportunity for reflection on the impact of activities over the previous decade, and consideration of objectives looking ahead, taking into account the rapid pace of change in technology.

43. Under the terms of the BBC Agreement,[7] the BBC agreed to undertake and publish a review of its research and development activity, including:
    a. A cost benefit analysis (including an analysis of the value delivered for the public and the creative and wider economy);
    b. A qualitative assessment of the success achieved as a result of the investment in research and development activity, taking into consideration at least the previous Charter period, and up to the date of the review; and
    c. Consideration of objectives for the future, and potential ways in which the BBC may be able to improve collaboration with others to deliver increased value for the public as a result of this work.

44. The BBC has now concluded that review, and this report contains the findings. To inform the review, the BBC conducted three analyses which are summarised in this document:

    a. The BBC commissioned DotEcon, an economic consultancy, to carry out an independent analysis of the cost and benefits achieved by BBC R&D. DotEcon analysed a selection of case studies from across BBC R&D's project portfolio and, using microeconomic techniques, calculated the net benefits of each case. They used these results to model the overall benefits generated by BBC R&D as a

[6] BBC Agreement, December 2016, s65
[7] BBC Agreement, December 2016, s65(4)

whole, and compared this to benefits delivered by other applied research initiatives. DotEcon's full report is published alongside this review;

b. The BBC carried out a qualitative assessment of the impact of BBC R&D's key achievements during the Charter period and the benefits they delivered to our audiences, the BBC, and industry including the wider creative industry. The assessment was undertaken internally, combining the qualitative observations from DotEcon's analysis with a range of other internal and external sources; and

c. The BBC reviewed R&D's forward-looking objectives and potential ways in which its collaborations may increase public value. This review was also developed internally, through interviews with senior leaders across the BBC, and a review of BBC R&D's history of academic and industry collaboration.

45. The review is concerned with the activities described in the BBC Agreement section 65 (see above), that is *research and development activities geared to the fulfilment of the Mission and the promotion of the Public Purposes and which aim to maintain the BBC's leading role in research and development in broadcasting and other means for the distribution and consumption of audio, visual and audiovisual material and other content, and in related technologies.* Almost all of these activities take place within the BBC's R&D department, which is therefore the focus of this report.

46. The report is in four sections. It first sets out the rationale and purposes of BBC R&D activity. It then assesses the demonstrable impact of R&D activity over the 2007-16 Charter period, and lessons learned. It then addresses forward-looking considerations, and objectives for the 2017-27 Charter period, and sets out the conclusions of its review of collaboration. Finally there is a short summary of conclusions.

3. Why R&D matters to the BBC, its audiences and the wider media industry

The BBC's public service mission drives a distinctive approach to innovation

47. BBC R&D's activity is first and foremost for the benefit of audiences. And, because of the BBC's universal mission, it takes a particular approach to innovation, that seeks to bring the benefits of new technology to everybody. As the BBC's Chief Technology and Product Officer, Matthew Postgate, said in July 2017: "it is not just innovation that is in our DNA; it is also the ability to shape that innovation in the interests of society."[8]

48. Of course the BBC does not have a monopoly on socially valuable innovation. So BBC R&D must consider, in deciding where to prioritise its activities and investment, how to deliver distinctive public value. Because the BBC does not have to account to commercial shareholders, it can invest in areas or ways that the market would not.

49. These considerations are relevant even during a time of great commercially-driven technological change. In some respects they become more important, since as technology creates new opportunities, the BBC plays an important role in bringing the benefits to all audiences, and ensuring that new technologies are put to public service as well as commercial ends.

50. This review has identified four enduring drivers for the BBC's R&D activity: to deliver benefit to audiences and society, aligned with the BBC's public purposes; to give the creative community inside and outside the BBC the tools to enable it to fulfil the public purposes; to make what the BBC does cost-effective and value for money; and to deliver value to industry and the UK. We consider each in turn, with some illustrative examples. Typically, particular projects address multiple objectives, although we have emphasised the primary purpose of the case studies mentioned here.

Delivering for audiences and society in line with the BBC's public purposes

51. The BBC has a unique set of objectives, enshrined in its public purposes.[9] These purposes drive strategic priorities focused on delivering for all audiences and for wider social benefit.

52. For example, BBC R&D works to ensure new technologies, such as catch-up TV and Internet streaming, are available to all UK homes. This prompted the development of the YouView, Freesat and Freeview Play connected TV platforms, which enable audiences to discover and catch up on programmes, and benefit from the flexibility of connected capabilities, in a familiar EPG-driven interface in affordable integrated TVs and set-top boxes.

53. R&D can also enable the BBC to deliver new forms of value, linked to those purposes but not delivered through traditional TV, radio or online content.

[8] Speech by Matthew Postgate at BBC Blue Room Presents Artificial Intelligence and Society, 10 July 2017
[9] BBC Charter, s6

54. The BBC micro:bit provides an example from the 2007-16 Charter period – a platform that enables children to become coders and makers by using a simple programmable device, developed in a collaborative project by 29 organisations, including ARM, Microsoft, Samsung, The Wellcome Trust and Lancaster University, as well as the BBC. Over 950,000 micro:bits have been delivered to UK schools to give to every year 7 student.[10] The micro:bit supports the public purpose of promoting education and learning, in a highly cost-effective way: the project evaluation found that nine out of ten students who used the micro:bit agreed that it helped show them that anyone can code, and a similar proportion agreed that coding isn't as difficult as they thought it was. 39% of girls who used a micro:bit said they would definitely choose ICT/Computer Science as a subject option in the future, compared to 23% before using it.[11]

55. Finally, BBC R&D carries out research that addresses the needs of particular groups that may be underserved by commercial providers. For example, to help ensure content is universally accessible R&D conducted user research into subtitles (used by over 7.6m UK adults, including 1.4m with hearing impediments[12]). The results showed that audiences strongly preferred subtitle speeds that match the speed of speech, prompting Ofcom to revise its subtitling guidance, and enabling all broadcasters to deliver a better subtitling service. R&D chairs the Digital Video Broadcasting (DVB) subtitles group, and has worked on techniques to synchronise live subtitles.

Giving the creative community the tools to fulfil the BBC's public purposes

56. Technology and creativity evolve hand-in-hand; each drives the other. A creative organisation with weak innovation capability risks falling behind in today's intensely competitive media market. In the BBC's case, early experiments with online and picture quality improvements paved the way for future mass market deployments that added great value to audiences' experiences of the BBC, and ensured that the BBC remained competitive. In the 2017-27 Charter period, the same may be true of Virtual Reality (VR) and Augmented Reality (AR). Sometimes technologies do not achieve the impact that the market expects, as with 3D TV, although they often deliver insights that prove valuable in other areas. R&D must balance the need to ensure the BBC remains relevant and competitive with the inevitable risk of experimenting with early-stage technology.

57. Three examples illustrate the symbiotic relationship between technology and creativity. First, in 2015, BBC R&D and BBC Television launched BBC Taster as a platform to host the experimental pilots being developed within BBC Connected Studio and across the BBC. The BBC has since opened up the platform to other British cultural organisations, for example the Ai Weiwei 360 at the Royal Academy, thereby making it possible for people who could not come to London to explore the exhibition. BBC Taster facilitates engagement between audiences and storytellers; audience members provide feedback on their experiences and content makers explain the concept and how it was made. 200,000 visitors come to BBC

[10] Every Year 7 student in England and Wales, every Year 8 student in Northern Ireland, and every S1 student in Scotland

[11] Source: Discovery Research – online survey conducted July 2016, among a representative sample of 405 x UK Year 7 students. http://www.bbc.co.uk/mediacentre/latestnews/2017/microbit-first-year

[12] Ofcom, Ofcom publishes third report on quality of live TV subtitles, May 2015

Taster each month, and 78% of people who rate a pilot provide detailed feedback about their experience.

58. Secondly, Redux. The BBC owns one of the largest audiovisual archives in the world. However, prior to 2007 the archive lived on physical tapes that had to be requested from facilities at Elstree and physically delivered to wherever the person who wanted them was based. It was very difficult to search this archive and extract content from it. BBC R&D built Redux, a tool to capture television and radio programming directly from broadcast and store relevant data alongside it, creating a recent archive that is instantly searchable and accessible. This tool has enabled BBC creative teams to experiment with using the content and associated data in different ways, giving them access to the 3m programmes stored on the platform, enabling rich creative uses of archive material as well as saving money. Snippets, software that automatically matches broadcast subtitles to the broadcast output, makes Redux even more useful to content makers as it can navigate a user to the exact point in the programme where a search term or phrase is used. Users can then easily 'snip' the relevant clip for use in their content. BBC users snip over 44k clips each year and users report that the system saves them significant time researching, requesting, and transcoding archive content. In addition, Redux/Snippets has increased the amount of archive footage that producers use in their content, improving the quality of programming, and in cases of news and historical programming, preserving the UK's cultural history. Redux also delivered a number of wider benefits, including contributing some of the technology that supported early versions of BBC iPlayer, and developing meta data and tagging capabilities used in the newsroom.

59. Thirdly, the BBC has found that, in the hands of skilled storytellers, data itself can make interesting content. For the latest series of 'Child of our Time'[13] R&D built a mobile application to collect and analyse mobile phone usage amongst the show's 25 teenagers. The application captured data on screen time, apps, web history, calls and messages, while safeguarding the teenagers' privacy. The data and its visualisations became the organising principle of the show's narrative, and were used to explore how their phone use impacted the children's friendships, sleep and anxiety. The episode was watched by over 2.4m viewers. BBC R&D also used its data science expertise to analyse five years of chart-topping songs to understand the composition of the perfect song for 'The Secret Science of Pop.'[14] Working with academics from several universities, BBC R&D used signal processing techniques to evaluate variables such as tempo, key, melody, and rhythm to develop a unique blueprint for each song. 'The Secret Science of Pop' explored this analysis in depth, applying the findings to predict which songs submitted to BBC Introducing would succeed.

Cost-effective innovation and value for money

60. R&D can help deliver financial benefit to licence fee payers in a number of ways. It can help reduce the BBC's direct costs, or avoid anticipated future cost increases; for example, the BIDI project (see section 4) will give the BBC more control over its Internet distribution costs, saving money in this increasingly business-critical area. DotEcon assessed the savings from Redux, described above, at between £53-59m over the 2007-16 Charter period,

[13] http://www.bbc.co.uk/programmes/b0072bk8
[14] http://www.bbc.co.uk/programmes/b08gk664

achieved at a cost of £1.4m. R&D can also make innovation affordable by creating efficient ways to deploy new technologies, such as the AS-11 file standard that has dramatically simplified production processes by making all content files interoperable.

61. And R&D can create assets capable of commercial exploitation, delivering returns that are ploughed back into content and offset cuts in licence fee funding, such as the Piero sports graphics system, described in section 4. The BBC Agreement recognises that the BBC will sometimes face trade-offs between generating revenue through commercial exploitation of its intellectual property, and the value that might be delivered to the public and the UK economy by making new developments widely and openly available. It requires the BBC to achieve an appropriate balance between these two aims. Neither is dominant, and the right balance has to be judged on a case by case basis. R&D's patent portfolio is an important tool in achieving this balance – it enables the BBC to explore commercial opportunities, working with partners, but also gives the BBC influence over how the technologies it has developed are used and built on, including making them freely available or licensed on fair, reasonable and non-discriminatory terms.

Delivering value to industry and the UK

62. R&D's approach has always been collaborative and open, seeking to bring the benefits of its work to the wider industry. Key relationships in the 2007-16 Charter include its joint venture platforms (Freeview, Freesat and YouView, co-owned by the BBC, other broadcasters and network operators); the forums it created to develop innovative IP production technologies; and its participation in Internet and mobile standards groups.

63. BBC R&D provides platforms that offer new routes to market for creative talent, entrepreneurs and developers. For example, the BBC Backstage programme built a community of web developers who created new experiences using BBC assets. It made available BBC data on a trial basis for third parties to use in online projects. The programme generated over 500 prototypes over five years. The programme's successor, BBC Connected Studio, sought to make it easier for SMEs to work with the BBC on innovation projects, including streamlining procurement processes, and simplifying contracts and intellectual property arrangements. Over 520 companies have participated in the programme's workshops, studios, and requests for proposals, yielding 168 contracts for the development and testing of new online concepts. BBC News Labs (an innovation incubator that works with academic institutions and other news organisations to develop storytelling tools and open standards for news) and BBC Reality Labs (a similar collaborative project on VR and AR) evolved from BBC Connected Studio initiatives.

64. The BBC's scale, technical capability, audience reach and independence enable it to play a convening role, bringing partners together to work collaboratively on behalf of the wider sector. While this may cause tension with organisations with different strategic agendas, both the qualitative and economic assessment carried out for this review (described in section 4) suggest that the pros of coordination outweighed the cons.

65. R&D has been particularly influential in driving the development of open standards, interoperable technologies and open platforms. Industry forums, whether UK, regional or global, play a central role in defining the way new technologies are developed. R&D's

contribution has helped to ensure that new technologies are widely available and capable of being used by all industry players, and that standards and technical profiles meet the BBC's and other broadcasters' needs, including increasingly engaging in mobile and Internet standards and industry groups (more detail in section 5). This contribution has been vital in enabling broadcasters to bring new services to market, ensuring they are reliable and capable of being rolled out across multiple receiving devices and browsers.

66. For example, BBC R&D has a long-standing relationship with NHK, the Japanese public service broadcaster. Joint activities range from advances in video compression techniques to co-development of a technique for delivering more vivid colours, known as high dynamic range (HDR), with a solution called Hybrid Log Gamma (HLG) (see section 4). R&D is working with consumer electronics manufacturers to ensure that televisions in the market are able to receive and display HLG content, including making test content available. It has also provided advice and insight to other content providers, including YouTube, who subsequently adopted the HLG standard for UHD content.

67. The BBC has also pioneered new IP-enabled live production techniques. In doing this it has convened suppliers to the broadcast industry in a global effort to create interoperable solutions. These solutions represent valuable new products for those suppliers and create an attractive capability to the broadcasters that buy them. As these products are taken up by broadcasters they promise to reduce broadcast costs, for example in coverage of live event, delivering high quality broadcasts without the need for full-scale crews and infrastructure.

68. These activities deliver value not only to the BBC, but to the wider economy, both through direct benefits to partners and spillover benefits to the wider broadcast and audiovisual sectors. DotEcon's analysis of these benefits in the 2007-16 Charter period is summarised in section 4.

4. Assessment of the impact of BBC R&D, 2007-16

BBC R&D employs just over 200 people

69. BBC R&D currently employs c. 205 people, based in research laboratories in Salford and London. Its workforce is comprised of specialist research engineers, scientists, ethnographers, designers, producers and innovation professionals working on every aspect of the broadcast chain. R&D teams work with industry and academia to lead the invention of new forms of content and new ways to deliver it, increasingly focused on Internet-enabled technologies. R&D staff also work alongside BBC experts in other creative and technical teams.

70. Over the course of the 2007-16 Charter, BBC R&D costs amounted to £161m. This section assesses the impact of the BBC's R&D activities over that period, with respect to audience outcomes, value for money, benefits to industry and economic value to the UK. This draws on both the internal qualitative analysis conducted by the BBC and the independent economic analysis conducted by DotEcon. Both studies are based on an analysis of a range of illustrative examples of R&D activity, and do not seek to describe everything R&D does. However, DotEcon has developed aggregate estimates of R&D's total economic benefit, based on its analysis of selected case studies, and described towards the end of this section.

BBC R&D delivered benefits to audiences and society

71. In the 2007-16 Charter period, BBC R&D sought to innovate in the nature of the content the BBC provided to audiences, production tools and technologies, and methods of distribution. Improvements included better picture quality, innovative sport graphics, greater accessibility through improved subtitles, and many other new information and entertainment experiences. R&D innovation also enhanced the BBC's coverage of national events like the UK General Election, Glastonbury, and the Olympics.

New creative experiences

72. BBC R&D played an active role in helping the BBC to evaluate emerging new technologies and to develop, test and trial new experiences and their suitability for different content genres. For example, BBC R&D's early activities in commissioning 360-video and VR made the department a key resource for the rest of the BBC, demonstrating what is possible and providing expert advice on VR technology and storytelling techniques to help make VR productions across several genres. In 2017, the BBC created a new VR Hub to manage all BBC VR commissions, appointing BBC R&D's VR lead as the Head of VR Commissioning. Two of BBC R&D's VR commissions won prestigious awards:

    a. 'The Turning Forest,'[15] an animated VR film, won the TVB Award for Achievement in Sound, and it has been downloaded tens of thousands of times across the world; and

[15] http://www.bbc.co.uk/taster/projects/turning-forest

b. 'We Wait,'[16] an animated VR story about the refugee crisis told from the perspective of a Syrian refugee, won the Broadcast Digital Award for Best VR Experience

73. BBC R&D worked with partners to develop binaural audio in a pioneering, long-range initiative which involved five years of development. Binaural audio creates a spatial soundscape for headphone listeners, as if the listener were physically present at the scene. It gives the audience the impression that a sound source is located at a given location in space, so that the listener perceives sounds to be coming from above, behind, below, left and right. BBC Radio 3 and Radio 4 made several plays and concerts available in binaural audio and a binaural episode of Doctor Who was created, 'Knock, Knock', which enhanced the creepiness of the show by letting the house at the centre of the story creak all around the listener.

74. Finally, BBC Taster, described in section 3, had significant audience impact. In 2016, it averaged over 200,000 monthly viewers, with an average of 3.8 page views per visitor. Of over 250 pilots, 46 were rated at 4 or 5 stars out of 5. BBC Sport's Live Guide beta, a webpage that lists current, upcoming, and catch-up BBC Sports coverage, received 2.1m page views; Your Story, an interactive feature that shows world history through a personalised timeline and won the World Summit Award for eMedia and Journalism, gained over 1.8m page views.

Enhanced quality

75. Improving TV picture quality was a major focus of the last few years, which R&D was intimately involved in, including ensuring that free-to-air terrestrial TV viewers were not left behind by the move to HDTV. HD uses five times more pixels than standard definition (SD) and requires more data to transmit its richer images. BBC R&D chaired the international committee that developed DVB-T2 and engaged with industry to encourage adoption of the standard. DVB-T2 is a technical specification that enabled HD broadcasts on digital terrestrial TV and is more efficient and resilient than its predecessor, DVB-T, and its implementation, together with the adoption of MPEG-4 compression, initially freed up the capacity to launch three high-definition channels without requiring a reduction in the number of standard definition channels. BBC R&D's ongoing work to optimise capacity on the terrestrial platform enabled the launch of three additional HD and two SD channels on the BBC's multiplex over the Charter period. DotEcon assessed that R&D's contribution had helped to bring forward the launch of HD on terrestrial TV by three years, delivering a total economic benefit of £77-152m, for a cost to BBC R&D of £2.8m.

76. BBC R&D continues to lead the industry in preparing for the next step-change in picture quality, Ultra HD (UHD). In collaboration with the Japanese public broadcaster, NHK, BBC R&D invented and standardised the high dynamic range (HDR) standard that enables improved picture colour and detail in lowlights and highlights. The BBC's hybrid-log gamma (HLG) solution, developed in collaboration with NHK, was adopted as part of the ITU BT.2100 standard and ensures compatibility with existing production equipment. The BBC has already started using HLG, for example by post-producing Planet Earth II in HLG HDR,

[16] http://www.bbc.co.uk/taster/projects/we-wait

and plans to make Blue Planet II available in UHD HDR on BBC iPlayer. Planet Earth II was automatically converted to HDR10, using R&D technology, for its release on Blu-ray.

77. BBC R&D also collaborated with industry and other broadcasters to help reduce changes in the volume between programmes and trailers that detracted from the viewing experience. Loudness variations, where sound volume unexpectedly increases or decreases following the start or end of a programme or trailer, had been a source of BBC audience complaints for several years. BBC R&D contributed to the development of measurement techniques and production and distribution practices to minimise loudness variations, and worked with the European Broadcasting Union (EBU) to standardise these solutions so that other broadcasters and audiences would benefit. The standard has been adopted by 17 European countries.

Bringing the benefits of new technology to all audiences

78. The BBC was given an explicit mandate to work with industry partners to deliver digital switchover in the 2007 Charter, as noted in section 3. The switch from analogue to digital broadcasting freed up valuable spectrum for mobile use, and allowed TV multiplexes to be retuned to reach more of the UK and host additional channels. By the end of switchover, the expanded choice offered by digital terrestrial television was available to over 98.5% of the UK population. For those who remained outside the range of terrestrial broadcast, BBC R&D developed Freesat, which launched as a joint venture with ITV in 2007.

79. In parallel, BBC R&D helped transform the way in which audiences access BBC content online. BBC iPlayer launched at the beginning of the 2007-16 Charter period. At that time it was only available on PCs, later launching as an app for mobile devices and smart televisions. Insights developed by R&D materially informed the development of iPlayer and its subsequent integration into TV platforms, building on its long history of online innovation and many of the technical advances it made in the 1990s and early 2000s.

80. BBC R&D architected two new consumer platforms, YouView[17] and Freeview Play, to help make online TV available to all UK audiences, via user-friendly EPG-based interfaces. Both were launched in partnership with others. YouView, a joint venture between the BBC, ITV, Channel 4, Channel 5, BT, TalkTalk and Arqiva, was used by 2.26m households in the second quarter of 2017.[18] Freeview Play was launched in 2015 by Digital UK, a joint venture between the BBC, ITV, Channel 4 and Arqiva, to promote Internet-enabled services even more widely. Over half of all smart TVs sold now include Freeview Play, and over 1.5m Freeview Play sets have been sold since 2016,[19] helping to maintain the viability of the free-to-air TV market. TV sets account for 114m iPlayer requests every month, a 48% share of all monthly requests.[20]

[17] BBC R&D developed technology that inspired the formation of the YouView joint venture, which it subsequently licensed to the company for commercialisation. R&D continued to provide YouView technical support until the service launched in 2012
[18] BARB, The UK Television Landscape Report, January 2017
[19] Freeview, Freeview Play sales surge, July 2017
[20] BBC iPlayer Performance Report, September 2017

BBC R&D developed tools that enabled the creative community to meet the BBC's public purposes in new ways

81. In the 2007-16 Charter, BBC R&D trialled Object-Based Media (OBM), technology that develops the interactive potential of online video and text. OBM has been used to make more engaging and interactive news articles, for example through a pilot with youth-focused news brand Newsbeat, called Newsbeat Explains, and a 'General Election: What you need to know' website.

82. Newsbeat Explains is a mobile-first prototype that breaks away from conventional linear news articles. Its articles are presented as a short overview of key points that can be expanded to reveal more detailed information and links to key concepts (e.g. people, places, organisations). Audiences can consume the story in any order they choose, and journalists can easily reuse the content in other stories. 'General Election: What You Need to Know' built on this format, making the vast amount of election information more readily accessible by breaking it into small, independent parts. Making news increasingly accessible to young people is a priority for the BBC, and delivering news stories in these ways has supported engagement with this demographic.[21] These projects inspired a new article page format for news and informed the development of the system for managing news content, which will include object-based functionality.

83. BBC R&D has also shown how OBM can be used to repurpose content from programmes to create new experiences. It created a database structure that captures storylines, key events, and character timelines across multiple episodes and seasons. The team behind 'Peaky Blinders', a drama set in 1920s Birmingham, used the database to create a mobile catch-up experience. This enabled the audience to explore storylines from the previous seasons, with clips of key moments, ahead of the new season's premiere.[22] The team behind Homefront, a World War One continuing radio drama, used the platform to create a companion to the programme that allowed listeners to explore storylines that had played out over multiple episodes and seasons.

BBC R&D supported cost-effectiveness and value for money

84. The Internet bandwidth needed to deliver the BBC's online services is growing rapidly, driven by increased demand for connected television, online and mobile viewing, and increasing picture quality. This risks increasing costs and making the BBC more dependent on third-party Internet distribution providers. Over the 2007-16 Charter period, BBC R&D began exploring Internet distribution options to mitigate these risks.

85. In order to be able to distribute some of the BBC's online content in a more sustainable way, BBC R&D was instrumental in developing and piloting an in-house Content Delivery Network (CDN) called BIDI (BBC Internet Distribution Infrastructure). This was deployed partly inside BBC data centres and partly embedded in large Internet Service Providers (ISPs). The BBC's objectives were to manage its distribution costs in a more predictable manner, to facilitate a closer relationship with ISPs for future innovation, and to gain

[21] BBC R&D Blog, Mobile-First News for Young People - Our Findings from Newsbeat Explains, May 2017; BBC News, General Election: What you need to know
[22] BBC R&D Project, Story Explorer

technical visibility over its distribution channels and greater control so that it could optimise for performance as well as cost. R&D's initial prototype deployment of BIDI has evolved into a service managed operationally by the BBC's Online Technology Group. BIDI now carries a significant proportion of the BBC's Internet media streaming sessions to licence fee payers.

86. The Piero sports graphics system provides another example. R&D created graphic overlays to sports action including showing the speed of a ball, who is in front of or behind the offside line in football, or the movement of players in a complicated play. Piero's 'splash-ometer' helped over 15m UK viewers understand how Tom Daley's splashes compared to his rivals' as he competed at the 2012 Olympics, and over 3m viewers see Piero graphics in action each week during Match of the Day.

87. Beyond these creative benefits, Piero delivered significant economic value to the BBC. BBC R&D collaborated with Ericsson to develop a commercial product based on the Piero system. DotEcon estimated that it has delivered between £46-77m benefits to date, comprising royalties, cost savings to the BBC, and value to audiences, for a cost of just over £1m.

88. R&D's investment in meta data enrichment and speech-to-text will also deliver significant cost savings. The BBC has a high demand for transcription services to convert broadcast content into speech. Its efforts to create automated means of understanding content led to the creation of an in-house speech-to-text system (BBC STT) that has been used to transcribe over 1m video assets. STT evolved from BBC R&D's long-term research into natural speech and was developed from lessons from the 2015 Multi-Genre Broadcast Challenge, which gave academic institutions access to BBC data and challenged them to improve speech-to-text performance across broadcast genres using open-source technology. BBC R&D's evaluation of speech-to-text services showed that BBC STT outperformed the accuracy of most commercial solutions, and is highly cost-effective; while commercial providers charge £1-£5 per hour of content, the BBC's operating costs are a few pence per hour. In addition, BBC STT produces transcripts of audio and video content in seconds, instantly creating searchable meta data for the content. It is now used by around 30 teams in BBC News.

BBC R&D delivered value to industry and the UK

89. In all these areas, R&D depended on partnership with industry and academia. Collaboration has been, and remains, essential to R&D's operating model. This includes multi-year strategic collaborations, such as the Audio Research Partnership and UX Research Partnership (see section 5 for more details); collaboration as part of standardisation forums and industry bodies; and bilateral or small-group industry collaboration, such as the partnership with NHK described above.

90. Between 2007-2016, BBC R&D catalysed two significant shifts in TV production with wider benefit. First, it simplified the process by which programme files are transported between broadcasters, production houses, and post production companies in an approach that has been adopted across the UK and increasingly globally. BBC R&D helped create, then worked with the Digital Production Partnership (DPP) to develop the AS-11 file standard, which transformed the production process by making all content files interoperable. This standard

built on BBC R&D's previous work on enabling compatibility across different manufacturers' production equipment. The standard has been adopted across the UK. Since 2014, over 25,000 programmes have been delivered as AS-11 DPP files and since October 2017, UK broadcasters have only accepted programmes in AS-11 format.

91. The second major transition BBC R&D inspired is in making new production systems work exclusively over the Internet. The global broadcasting industry traditionally relied on bespoke hardware and networking technologies designed specifically for the broadcast environment. As Internet-based networking became ubiquitous and its performance was projected to reach broadcast requirements, BBC R&D saw an opportunity for the broadcasting industry to transition to an IP-driven, software-based approach that would be less dependent on specialised equipment and able to support more flexible workflows, such as remote production.

92. At the time BBC R&D began exploring these concepts, there was no consensus in industry that IP production would work, or an aligned view as to how it might be enabled. The department led efforts to ensure that new standards and norms would enable these new capabilities across the whole industry. It convened a new industry body to develop the architecture and a collaborative working group, the Networked Media Incubator, to develop, test and standardise technologies using this approach. The Commonwealth Games in 2014 gave R&D an opportunity to prove the concept, by running a live production entirely in IP.

93. The technology is now sufficiently mature that industry is adopting it at scale. The International Broadcasting Convention (IBC) in 2017 featured many compatible products. The Alliance for IP Media Solutions (AIMS), an industry body that promotes solutions compatible with these standards, has over 76 members including Sony, Cisco and NBC Universal. The IP architecture is expected to deliver cost savings to the global industry as well as significantly enhanced creative capabilities compared to legacy technologies.

94. On the distribution side, BBC R&D worked with a range of industry partners to develop DVB-T2 technologies, as described above, and then protected them with patents in order to make them available on a fair and reasonable basis, making the standard viable for manufacturers to invest in and to build compatible equipment. The global media industry has also benefited: DVB-T2 has been adopted by 166 countries, creating economies of scale for electronics manufacturers selling DVB-T2 compatible equipment around the world.

95. Across a range of initiatives, BBC R&D often acted as ambassador for, and convenor of, the whole UK broadcasting sector in international forums. Examples of the department's instrumental role in standards development span from more traditional core broadcasting technologies to standards that support broadcasters' transition to Internet and data-driven production, distribution and content. Examples include BBC R&D's engagement in the Digital Television Group to develop and maintain high quality free-to-air television in the UK; participation in W3C and 3GPP Internet and mobile forums; and contributions to standardisation and industry bodies to enable improvements in picture quality and

compression techniques such as DVB-T2,[23] HDR,[24] HEVC[25] and the Alliance for Open Media.[26]

96. BBC R&D also contributed to global media technology research and development through its academic contributions. Over the Charter period, BBC R&D staff published over 200 articles and papers, and delivered over 280 lectures. An extensive collection of the Department's White Papers dating back to 1974 is available on the BBC R&D website, attracting technical users from around the world. The BBC R&D website also provides an introduction into the department's research for less technical visitors, with films, blogs, and illustrations that explain complex technical concepts in an accessible tone.

97. Training and skills development – often as part of collaborations with external partners – are a core part of the department's activities. Sixty graduates joined R&D's trainee scheme between 2006-17, and several industrial trainees came into the department on one-year contracts. Both the BBC and the wider industry benefit from the skills and expertise of BBC R&D's alumni when these take on opportunities outside the department. During the previous Charter period, nine former BBC R&D staff went on to senior roles elsewhere in the BBC. Within industry, over 25 BBC R&D alumni now occupy senior technical roles in organisations as diverse as Cisco, Dolby, Netflix, Inmarsat, Pivotal, Ooyla, Ofcom, Digital UK and Cambridge University.

Economic benefits: DotEcon's independent assessment

98. The BBC commissioned DotEcon, an economic consultancy, to provide an independent evaluation of the costs and benefits of R&D's work over the 2007-16 Charter period.

Methodology

99. DotEcon's assessment is based on its own analysis of raw data provided by BBC Finance and R&D. In addition, it interviewed senior stakeholders in BBC R&D, the wider BBC and individuals working in related areas of the broadcasting sector.

100. DotEcon analysed a selection of case studies from across BBC R&D's project portfolio and calculated the net benefits of each case. It selected seven case studies of projects to include work across all areas of the broadcast value chain. Using microeconomic techniques, the team estimated the cost-benefit ratios delivered by these projects. The identified benefits include:

    a. Direct benefits to BBC viewers and listeners

    b. Direct benefits to the BBC (cost savings and licence revenues, audience time spent with BBC services)

    c. Spill-over benefits to the broadcast and audiovisual sectors

[23] http://www.bbc.co.uk/rd/projects/dvb-t2
[24] http://www.bbc.co.uk/rd/projects/high-dynamic-range
[25] http://www.bbc.co.uk/rd/projects/video-coding
[26] http://www.bbc.co.uk/rd/blog/2016-10-alliance-open-media-video-compression

101. The team measured costs incurred by BBC R&D, including labour, equipment, and other expenditures.

102. DotEcon used a weighted average of the cost-benefit ratios from five of these case studies to determine an overall average ratio:

    a. Weights were determined by the expenditure on the respective projects – this takes into consideration that costs can vary considerably from project to project, and ensures that those case studies that represent a larger proportion of R&D's spend are given greater significance in the calculations;

    b. In light of particular uncertainties about the magnitude of benefits from subtitles and BIDI case studies, the cost-benefit ratios from these studies were excluded when calculating the overall average ratio

103. This overall average ratio was then applied to BBC R&D's total spend to calculate total benefit. Two further adjustments were made:

    a. Some R&D costs did not deliver benefits consistent with this ratio, for example because some projects that did not deliver the expected benefits were stopped at an early stage, or because other projects have yet to deliver benefits but are expected to do so in future; and

    b. Larger projects have generally delivered larger benefit than smaller projects. (Successful projects attract money to translate this success into impact; therefore money tends to be an indication of success).

104. Therefore, to estimate overall benefits from all R&D activities, DotEcon only applied the overall average cost-benefit ratio from the case studies to large, successful projects (defined as projects over £700,000). It conservatively assumed that all smaller projects do not generate any benefits.

105. Finally, DotEcon benchmarked its findings against similar innovation impact assessments.

106. DotEcon calculated the benefits of the chosen case studies as a range, given the difficulties of precisely measuring benefits that are to some extent intangible. Consequently all cost-benefit ratios are similarly expressed as a range.

Headline findings

107. The five case studies assessed to generate the overall average cost-benefit ratio delivered total benefits of £24-£34 for every £1 of R&D cost.

108. Once these projects were aggregated to cover all BBC R&D, with smaller and unsuccessful projects assumed to deliver no benefits, DotEcon found a net benefit of between **£5-9** for every £1 spent by the department. This equates to **a total economic benefit of between £827m - £1.40bn over the whole of the 2007-16 Charter period, relative to costs of £161m.**

109. DotEcon ran a sensitivity analysis which found that if the cut-off point for 'large successful' projects were lowered, benefits generated by BBC R&D could be assessed as £2.57bn, resulting in a cost benefit ratio of 1:16 for the department over the 2007-16 Charter period.

110. DotEcon cites several benchmarks that show similar cost-benefit ratios arising from other research and development programmes. These included a review of InnovateUK's 'Smart' R&D financing programme that generated cost-benefit ratio between 1:4 and 1:5, an evaluation of the Technology Strategy Board's Collaborative Research and Development programme that found £6.71 in benefit for every £1 spent, and the EU Horizon2020 programme that expects to deliver benefits of in the range of €6-8 for every euro invested.

Analysis of case studies

111. DotEcon's findings for each case study project are summarised in Table 1. Full details of each case study are included in DotEcon's report, published alongside this review.

Table 1: Summary of DotEcon case study analysis

Case study	Position in value chain	Costs (£m)	Benefits estimate		Cost-benefit ratio	
			Lower bound (£m)	Upper bound (£m)	Lower bound	Upper bound
Piero	Content	1.08	46	77	42.6	71.3
Redux/ Snippets	Data, Content Analysis, Storage	1.39	53	59	38.3	42.2
Connected TV platforms	Distribution	3.40	33	49	9.56	14.6
DVB-T2	Distribution	2.78	77	152	27.6	54.6
AS-11	Production	0.48	12	12	25.7	25.7
Subtitles[27]	Production	1.18	25	> 25	21.2	> 21.2
BIDI[28]	Distribution	0.38	Not quantified			

Learning lessons

112. This review identified some R&D projects that provided opportunities to learn for the future. Examples include:

    a. BBC Backstage (see section 3) was R&D's first effort to engage with third party innovators at scale. It attracted thousands of participants from companies like Yahoo, Google, BT and ARM, and yielded over 500 prototypes in its five-year tenure. These prototypes helped to test out ideas that informed future BBC Online products. The BBC's experience in running this programme provided lessons about working with third parties that informed the BBC R&D's next collaboration programme, Connected Studio, and led to the development of

[27] Excluded from weighted average calculations as a result of the uncertainty in estimating both the true social value of subtitles and the value of the quality improvements achieved

[28] Excluded due to non-disclosure agreements regarding BBC's current costs for use of third party CDNs

projects like BBC Juicer,[29] a news aggregation and content extraction API; BBC News Hack,[30] a programme of journalism-focused innovation projects; and the Future of Content programme,[31] designed to inspire the development of innovative digital experiences for BBC Online;

b. BBC R&D undertook a review of emerging 3D television capabilities as part of a broader project looking at the future of TV. This included an evaluation of 3D stereoscopic displays, in anticipation of industry moves to promote these technologies, and development of trial content including an experimental 3D broadcast of Wimbledon in 2011. However it chose not to launch a dedicated 3D service, and therefore its cost exposure was limited. In the event, as mentioned in section 3, 3D TV proved unable to achieve mainstream adoption and scale, and has generally been shelved by broadcasters. The insights gained through earlier 3D research were applied elsewhere, including in Piero; it is important that even curtailed lines of research are mined for insights that may help develop a more fruitful seam elsewhere;

c. Stagebox was an early project within R&D's IP Studio. From a technical perspective, the project successfully implemented live bi-directional capabilities over IP networks. It was used on several high profile programmes including the UK Local Election, 2012 Olympics, Oxford & Cambridge boat race and the US Elections, and the technology developed in the project was used on subsequent projects. However, the returns from licensing the design to external partners were lower than expected; and

d. BBC R&D's work on the halfRF project developed first HDTV and then UHD wireless radio camera systems using MIMO technology (multiple input-multiple output, which is a multiple antenna technology). The project brought significant benefits in terms of ruggedness and spectral efficiency. Prototype camera transmissions systems were produced and demonstrated, including at events such as the International Broadcasting Convention (IBC), and the project produced several spin-off benefits including input to the DVB Next Generation Handheld standardisation, a number of patents and know-how that can be used in further research work. It was hoped that the UHD wireless camera system would be licensed and manufactured to become available as a tool for the BBC, but this has not so far been the case, although it is still possible this could yet happen. One of the reasons is that one of the components is not sufficiently widely available; involvement of manufacturers at an earlier stage of the prototype development might have helped in its adoption.

113. These examples emphasise the ongoing importance for R&D of working closely with industry to incentivise take-up and ensure its projects are closely aligned to wider industry need. While this has been a hallmark of R&D's work over the last decade, and indeed throughout its existence, it will become increasingly important as the range of technologies

[29] http://bbcnewslabs.co.uk/projects/juicer/
[30] http://bbcnewslabs.co.uk/projects/news-hack/
[31] http://www.bbc.co.uk/connectedstudio/projects/future-of-content-interactive-video

the BBC must engage with expands. R&D investment by the private sector has grown over the decades, with much innovation now driven primarily by global businesses. Consequently the balance of the BBC's activity has also shifted over time, with it acting less often as lead developer, and more often as one participant in a wider industry collaboration.

114. These examples also illustrate how over time R&D's focus is shifting, from selective collaborations within industry forums or with relatively small numbers of joint venture partners, to providing the means for the BBC to engage with a much bigger constituency of creators. Different influencing strategies are needed to deliver benefit to this constituency, which has disparate objectives, and cannot be gathered around a single table.

115. Given R&D's resources are inevitably limited relative to the industry as a whole, it will need to focus its efforts both strategically and tactically. Strategically, it must prioritise the areas it can make most difference and deliver most distinctive public value, including understanding how it fits into a much broader and highly innovative creative sector. It is starting to work with shorter development cycles, with more projects lasting three years, and relatively fewer (although not none) lasting ten or more.

116. Tactically, it must use its leverage carefully to maximise impact. The right technical expert, in the right room, at the right time, can make an outsize contribution to technological development consistent with the BBC's public purposes.

117. Looking ahead, R&D should continue to prioritise opportunities where it can be a catalyst for broader change. By providing proofs of concept, supporting long-term development, convening and collaborating, the BBC can help open up new technical possibilities without itself contributing most of the technical effort – IP Studio 'plugfests' which brought developers together to create next generation tools, or the integration of connected functionality in free-to-view TV platforms, provide examples. In the next period, it should seek to provide stimulus to inspire tool-makers and content creators to exploit fully the potential of the new production and creative tools that R&D has helped develop in the last few years.

118. In the next section, we discuss how these lessons have been reflected in R&D's objectives for the next period.

5. Objectives for the 2017-27 Charter period

R&D's role remains vital, but needs clear strategic focus

119. Meeting the BBC's Charter obligation to maintain its leading role in research and development will require R&D to continue to evolve its focus. As the transition to Internet media continues, audiences' needs and expectations of the BBC will again change. The pace of technological change is high, and the range of technical areas that impact the BBC is broad; the BBC will need to use and shape emerging technologies such as machine learning, VR and AR to ensure that their benefits are made universally available and in line with the purposes of public service broadcasting, without unnecessary duplication of commercial activity. The media industry is increasingly global and intensely competitive. R&D therefore has to continue to be flexible, to work effectively in new technology contexts, with different standards and rules, and processes for setting them.

120. Collaboration has always been central to R&D's operating model, as described in the preceding sections. Over the years, its emphasis has evolved, with a new focus on Internet and mobile industry partners complementing its ongoing work with other broadcasters, and broadcast technology forums.

121. These new partners sometimes have different assumptions and norms for collaborating, and often have much greater financial resources than the BBC's. So R&D will need to maintain a tight focus on where it can deliver distinctive value aligned with the BBC's public service mission.

122. Three broad areas stand out as priorities for the next period. First, **distribution**, which was a major focus of the last ten years, will continue to be important. A key challenge for the BBC will be how to manage the transition to an Internet-led media distribution and consumption environment, while ensuring it takes all audiences with it and preserving the prominent, universal availability of public service content. New Internet and mobile standards will be central to this challenge, and R&D will play a vital role in ensuring that both the BBC's and the wider UK broadcasting industry's needs are met.

123. Second, **production**, where the emphasis will shift from creating the toolkit for IP production to reaping its benefits: experimenting with new forms of content and approaches to storytelling, unlocking the potential value of audience data, promoting the wide adoption of IP production standards and norms through industry groups, and creating structures that enable organisations across the entire media value chain to deliver new content experiences.

124. Third, these innovations will in turn enable the BBC to create new types and forms of **content**. While traditional long-form TV and radio will continue to deliver great audience value, the growth of adaptive, dynamic, responsive, interactive, immersive and sharable technologies will open up new ways to fulfil the BBC's public purposes and reach new audiences.

125. The remainder of this section describes the drivers of R&D's priorities in more detail, before defining initial objectives for the 2017-27 Charter period.

R&D's objectives are driven by wider BBC strategy

126. R&D's strategy and objectives are aligned with those of the BBC Design & Engineering division, of which it is part. The division's current goals are to build a world class technology division, drive the digital transformation of the BBC and be the catalyst for the BBC of the future. R&D plays an active role in all these objectives.

127. R&D's priorities are also set with reference to the BBC's wider strategic objectives and public purposes. As outlined in the BBC's Annual Plan for FY 2017/18,[32] the BBC's priority over the Charter period is to reinvent itself for a new generation. A number of strategic ambitions will help deliver this goal. 'Riding two horses' for a smooth transition to Internet delivery will be of key importance to the BBC. This means "serving those who have adopted the Internet as their primary medium while at the same time making sure that those who want to carry on watching and listening to traditional channels continue to be properly served, too."[33] The BBC has placed personalisation, participation and partnership at the core of its strategy in order to make its offer more distinctive and to ensure that everyone benefits. The organisation plans to reinvent its service for younger audiences, revitalise its education mission and grow its commercial entities BBC Studios and BBC Worldwide.

128. Very few (if any) organisations can match the engineering heritage and deep technology expertise of the BBC, and R&D in particular, paired with over nine decades of content innovation, constantly finding better and new ways to inform, educate and entertain. By combining this unique expertise with skills and resources of external partners, R&D seeks to reinvent the BBC's public services.

Renewing R&D's rationale in a new Charter period

129. Section 3 described the four rationales for BBC R&D. Our analysis suggests that these rationales endure, but R&D will need to continue to evolve to meet them in a changing strategic and technological context.

130. First, delivering **benefit for audiences and society**. R&D will help deliver the creative, high quality and distinctive content that is enshrined in the BBC's public purposes. Advances in Internet and data-driven technologies, increasing network connectivity, and evolving device capabilities such as voice recognition create exciting opportunities for experimental, innovative and personalised content. Embracing these technologies, and developing, testing and trialling them in collaboration with others, gives the BBC the opportunity to deliver its public purposes in new and better ways.

131. For example, BBC R&D is investigating how media experiences can be created that understand the physical environment and personal needs of the individual user and that adapt accordingly, taking into account elements such as location, lifestyle, age, the length of time that the user has available to enjoy a piece of content, or the user's depth of

[32] BBC Annual Plan 17/18, July 2017
[33] *Ibid.*

interest in a certain topic. The department will explore further how technologies such as VR, 360 video and AR can be used to create enhanced experiences that are more immersive and interactive than traditional TV and radio content, and are both more personal experiences and bring the nation together in new ways, for example around live public and sports events. R&D will experiment with new devices and ways of consumption to create content which tests new ways of experiencing BBC output.

132. BBC R&D will also continue to help the BBC deliver access services – allowing audiences to experience BBC content whatever their physical capability and wherever they are. For example, BBC R&D is working with iPlayer teams to improve subtitling through the introduction of newer standards and software.

133. With BBC services and consumption gradually migrating from broadcast to IP, ensuring that they remain universally accessible and free at the point of use will continue to be an important focus. R&D will play a central role in enabling a smooth transition path to Internet-driven experiences while at the same time continuing to steward reliability, accessibility and quality of traditional broadcast services.

134. For example, the new Charter period will see an increasing focus on 5G technologies and on trialling new types of content and technical capabilities together with external partners, following on from BBC R&D's trials of 4G and advanced 4G technology.[34] These types of collaborations with industry partners offer important opportunities (for BBC and all partners involved) to assess the technical and commercial viability and investment potential of new capabilities and therefore help to enable and shape standards development and adoption.

135. BBC R&D will seek to deliver new forms of public value, delivering distinctive societal benefit which is unlikely to be achieved by the market alone, and not solely through traditional TV, radio or online content. For example, the department will explore what data science and machine learning can do for the reinvention of public services. It is actively exploring how voice interfaces such as Amazon Alexa and Google Home can open up new exciting avenues for content discovery.[35] This includes assessing what types of content work well for speech-based devices, as well as developing ways of making speech-based applications adaptable across different platforms.

136. BBC R&D's work into natural language processing, techniques to extract semantic data, to classify content and to analyse sentiments will also enable better and faster discovery of content, for example through automatically classifying the mood of content pieces and using this mood classification for content recommendations. BBC R&D also continues to use machine learning to create more accurate speech-to-text capabilities and the department has been testing its system on different use cases such as improving social media 'shareability' and archive search.

[34] http://www.bbc.co.uk/rd/blog/2014-07-bbc-research-development-to-demonstrate-4g-broadcast-for-commonwealth-games; http://www.bbc.co.uk/rd/blog/2015-05-4g-broadcast-trial-wembley-2015-fa-cup-final
[35] http://www.bbc.co.uk/rd/projects/talking-with-machines

137. These new capabilities that data science and machine learning enable will contribute to making BBC content even more distinctive so that audiences can more easily find relevant and truly meaningful information, learning material and entertainment options.

138. Second, creating **tools for the creative community** to enable it to explore these opportunities in pursuit of the BBC's public purposes. The new Charter will see R&D intensifying its collaboration with internal BBC partners and independent production teams to stimulate use of the object-based production tools that BBC R&D and other providers have developed, and apply these to the production of new types of content.[36] The department has already initiated a workshop series with internal and external programme makers, developers, and creatives, so that they can create prototype ideas for new production tools and rapidly test them.[37] And the department is actively building communities of practice across the creative and production communities in order to explore together with external partners the possibilities that Object-Based Media has to offer for the future of media production.[38] As OBM approaches maturity, it will be important to establish standards and norms that enable an interoperable set of tools to co-exist. BBC R&D will need to work with existing and new industry suppliers to establish these.

139. Recent interactive object-based radio drama 'The Mermaid's Tears' provides an example. Listeners to this radio drama can choose to follow three different characters of the story, and depending on which one they follow will experience a different strand of the narrative. This radio programme was created using the tools and open protocols that BBC R&D has developed as part of the ongoing collaborative ORPHEUS project.[39]

140. BBC R&D is also investigating new capabilities that will allow for more interactive content, so that consumption moves from a one-directional (broadcaster-to-audience) activity to something that audiences can get actively involved in, connect over and share. For example, the collaborative project COGNITUS, led by BBC R&D, allows conventional professionally-produced high quality content in the Ultra High Definition (UHD) format to be enhanced and aggregated with user generated content (UGC).[40] The academic and commercial partners in COGNITUS aim to deliver innovative technologies to allow joint creation of very high quality media, exploiting both the knowledge of professional content producers and the ubiquity of unconventional content sources such as smartphones or portable cameras.

141. Tools initially developed for the consumer market may migrate to use in the professional setting, enabling innovation and allowing new entrants to come to market. For example, mobile phone capture is now used in newsgathering. As more people engage in content creation, for example through sites like YouTube, there has been a trend towards better quality consumer equipment (sometimes known as prosumer). With the growth of prosumer tools, and the blurring between consumer and professional content creation,

[36] http://www.bbc.co.uk/rd/projects/object-based-media-toolkit
[37] http://www.bbc.co.uk/rd/blog/2017-07-adaptive-stories-workshop-object-based
[38] http://www.bbc.co.uk/rd/blog/2017-05-object-based-media-events
[39] http://www.bbc.co.uk/rd/projects/orpheus
[40] http://www.bbc.co.uk/rd/projects/cognitus; http://cognitus-h2020.eu/

there is a risk of divergence of underlying approaches and standards, making one too hard or expensive to use in the other's context. As BBC R&D works with industry to develop open, interoperable, standards it will have a mind to the consumer context and, where appropriate, use its influence to promote technologies to be easy to use in both communities.

142. Third, BBC R&D will continue to drive **cost-effectiveness and value for money** across the BBC. It will continue to roll out BIDI to help manage costs of Internet distribution. It will build on the success of the initial rollout of speech-to-text to streamline the process of audio transcription across the organisation. The successful development of OBM will rely on its ability to make production as efficient and cost-effective as possible, as well as opening up new creative opportunity. And R&D will continue to develop low-cost live broadcast technology, working with industry, to further automate parts of the production process and streamline production costs.

143. R&D itself will continue to operate on a lean and agile basis. Relatively small teams or even single individuals can make a major impact in technology development, industry forums and collaborative projects – if they have the right expertise. Over time, the balance of effort and capability in the team will shift, as it has already – with an increasing focus on Internet-centric technologies blended with ongoing work on broadcast platforms.

144. Finally, R&D will deliver **value to the wider industry and UK**, particularly to promote the adoption of open standards and interoperable technologies. As outlined in section 4, BBC R&D has already played a key role in establishing the globally adopted approach to IP technologies in media production. In the 2017-27 Charter period these approaches will be adopted at scale, both in the BBC and across the industry. As creator and leading developer of the fundamentals, BBC R&D has an important role in sharing its know-how to assure effective adoption. This work has been, and will continue to be, a largely collaborative industry effort. BBC R&D will use the industry structures and relationships established over the last few years to do this.

145. Over the next few years, BBC R&D will experiment with methods of creating an open ecosystem which brings content makers, producers, creatives and consumers together and allows them to test, trial, innovate and share new media production tools and experiences. The department will investigate how such an ecosystem could be enabled at low cost and as openly as possible, enabling third parties to access it with as few hurdles as possible. This will involve research into the type of platform architecture and capabilities required to enable such an ecosystem. The feasibility testing and proof-of-concept will require R&D to encourage communities of practice to start using and contributing to this ecosystem, to test and add to its functionalities and build up its viability and scalability.

146. More generally, BBC R&D will continue to work closely with companies of all sizes to trial, test, and scale technology innovation. These collaborations range from SMEs to large manufacturers, in areas ranging from content production through to consumer electronics, either on a bilateral basis or as part of small groups.

147. With much data science and machine learning research driven by international players, collaboration will be important for BBC R&D in order to pair up public service assets, expertise and requirements with state of the art skills and resources elsewhere in the industry. Where possible and appropriate, it will make its technology, content and data assets available to academic centres of excellence (for example in the Data Science Research Partnership and Audio Research Partnership, see below). These projects illustrate that R&D's work is not only about creating new tools and standards, but also assessing emergent technology and inventions to assess their long-term relevance to the BBC.

Seven objectives for the 2017-27 Charter period

148. R&D has seven specific objectives aligned with the wider objectives of the BBC and the Design & Engineering division, and based on these drivers, shown in Box 1.

Box 1. R&D Objectives for the new Charter period

Content
Develop **new types of content for our audiences** that take advantage of IP and data-driven technology and that become more personal, interactive, immersive, adaptive, dynamic and responsive (for example, VR, AR and Object-Based Media).

Influence the development of the **next generation of audiovisual standards**, and prepare the BBC for their adoption in order to continuously improve sound and picture quality for our audiences in an internet-driven world.

Develop and test **new forms of value**, anchored in the BBC's public purposes, thereby taking advantage of what technology developments offer to create experiences for our audiences that go above and beyond the television, radio and online services that BBC audiences know and love today.

Production
Develop insights into **IP-led production technologies** that enable new types of content (e.g. data-driven, object-based) and that reduce costs and enhance creativity across the global industry.

Distribution
Support and improve existing distribution approaches and prepare BBC and industry for an **IP-led distribution future that supports our public service mission** and ensures that content (including new types of content and object-based experiences) is capable of being delivered in (and takes advantage of) **future distribution and consumption environments** (be it in the home, at work, on transport or in public spaces).

Data, Content Analysis and Storage
Capture and store **content, personal and meta data** in such a way that it can be efficiently and effectively used in creating new types of content, and **create the tools for analysing and using** that **data**.

Collaboration Platforms/Ways of Working
Provide the means to create a **collaborative ecosystem** for producers, content makers and audiences, taking advantage of Internet capabilities and functionalities.

149. These objectives may change over the 11-year Charter period. R&D's strategy must be capable of flexing in response to changing market, technological and competitive environments, and 11 years is a long time given the current pace of technological change in media. R&D has discretion to change its direction of travel over time, including revising its strategy, objectives and collaborative arrangements, as and when required.

150. To ensure that R&D spend, projects and collaborative arrangements remain appropriately focused on strategic priorities, the department has robust governance processes in place. It follows an annual work planning process that confirms priority areas of research for the coming year, with project reviews used to course-correct throughout the year. This annual plan is based on BBC-wide strategy, audience insights and its own assessment of future technology directions.

New collaborative models will be needed

151. Collaboration will be critical to BBC R&D's fulfilment of its objectives. It always has been. From orchestrating the industry around adoption of digital transmission standards; to coalescing public service and commercial companies around requirements for connected TV platforms; to inspiring a global industry to adopt new IP-based production standards; to establishing programmes of activity to engage creative SMEs in solving BBC problems; BBC R&D operates through collaboration.

152. However this Charter period will not be like the last. As highlighted above, the BBC is operating in new technology contexts with new competitors and doing new things. As such each of these objectives brings new requirements, but also challenges, to collaboration.

153. BBC R&D is already adapting to the requirements of collaboration in new spaces and with new types of partners. In the short-term it will use established mechanisms and is creating new collaborative relationships where those are not sufficient. But over the medium to longer term, there is a risk of excessive reliance on old models and established partnerships. As Internet business models, and online distribution, continue to grow in importance, it is likely that new relationships and new kinds of collaboration will begin to dominate. Specifically, this will include:

    a. Engaging widely with the creative and production community to translate technical possibilities into an industry that creates compelling audience experiences at scale;

    b. Creating mechanisms to engage with the wider industrial community who provide infrastructure and tools for media production and distribution, to create a technical ecosystem that is capable of supporting and delivering new types of content;

    c. Developing communities of practice to bring together early-adopting practitioners, for example through Connected Studio;

d. Continuing to engage with Internet and mobile standards groups to encourage the development of common standards that will make these new types of content universally available, including W3C, 3GPP and the DVB standards group;

e. Creating structures that enable organisations across the entire media value chain to adopt a coherent and interoperable set of solutions to deliver object-based and other data-driven experiences; and

f. Influencing the complex multi-stakeholder Internet ecosystem to enable universal, free-at-point-of-use access to BBC services.

154. In forming these relationships, R&D will need to continue to demonstrate to new collaboration partners that it can contribute constructively, and that Internet and mobile technologies must support public service principles, where these will not always be top of commercial operators' priority lists. The groups that define IP and mobile standards, which will have a significant bearing on the BBC's activity and the future of the broadcasting industry, are not forums in which broadcasters have traditionally had the strongest voice. And from its long history of innovating together with others, BBC R&D is aware that in collaborating there is usually a tension between achieving the best outcomes for audiences, the wider industry and public services. Intervening to achieve the optimal balance between these benefits in collaborative projects will remain an important role for the department.

155. However, much work has already been done to equip the BBC to engage effectively and in a value-adding way in the groups that will determine the nature of the Internet transition path for the UK broadcasting industry. For example, BBC R&D works with other companies in W3C to develop media-related standards for the web and is involved in various groups under the W3C umbrella. Since December 2011, BBC R&D has been chairing the Web Audio Working Group which seeks to add advanced sound and music capabilities to the Open Web Platform and is building on the functionalities brought by HTML5. Through its involvement in W3C the BBC builds valuable relationships with browser manufacturers, thereby being able to understand requirements and capabilities in an Internet-driven distribution environment, for example with respect to discovery and accessibility of content on Internet-connected TV distribution platforms.

156. R&D is also developing a new approach to academic collaboration, evolving from multiple small projects with individual academics into large, multi-year strategic collaborations with multiple universities. Examples include:

a. The wide-ranging Data Science Research Partnership, launched with eight UK universities to leverage academic expertise into data-related challenges faced by public service media.[41] This will include using data to create efficiencies and develop new creative formats; exploring the value of data as an asset, and how it can be used in ethical and trusted ways for collaboration and innovation; understanding the nature of media rights in an Object-Based Media world; and driving a public service strategy for in data research;

[41] http://www.bbc.co.uk/rd/projects/data-science-research-partnership

b. The Audio Research Partnership, which brought together five UK universities with audio expertise and resulted in two multi-million-pound programme grants.[42] Results so far have included an award-winning audio-led VR experience (working in collaboration with an SME), which was one of the titles made available by Google for the launch of its Daydream VR platform. Other results have included the provision of a baseline renderer for a new object-based audio system, now being standardised through the ITU; and

c. The User Experience Research Partnership with six partner universities.[43] This has supported partners in winning a total of £46m to establish four Digital Economy Research Hubs, and research outcomes have included contributions to new standards, guidelines and practices in the provision of accessibility support across mobile, tablet, PC and TV devices.

157. All these relationships, and the many other ongoing partnerships and collaborative initiatives that R&D contributes to, will play an important role in helping the BBC continue to transform itself into a 21st century, Internet-fit media organisation, operating for the benefit of all audiences and the wider industry.

[42] http://www.bbc.co.uk/rd/projects/audio-research-partnership
[43] http://www.bbc.co.uk/rd/blog/2013-07-bbc-rd-launches-the-ux-research-partnership

6. Conclusions

R&D is building on a solid foundation of successful innovation in collaboration. It must continue to adapt its convening, open and public service approach to changing market and audience conditions in the new Charter period

158. BBC R&D is building on a heritage of over nine decades of successfully driving innovation in collaboration with others in the UK broadcasting industry. Throughout this period it has demonstrated a consistent ability to create insights that deliver value, for audiences, for the creative community and the wider industry.

159. This has included pioneering the development and application of Internet technologies in the UK, playing a vital supportive role in delivering digital switchover, supporting content innovation, delivering ground-breaking IP production technology, and continually exploring new ways for the BBC to meet its public purposes.

160. In the 2007-16 Charter, it put in place the foundations for a renewed wave of innovation. The balance of its activities swung towards Internet-based opportunities. It established new relationships and demonstrated its worth in Internet and mobile industry forums and working groups, operating not only on behalf of its own audiences but also in the interests of the wider UK broadcasting sector. This review has highlighted the impact of R&D's activities over the last decade. It has worked closely and collaboratively with a wide range of industry and academic partners, including both long-range partnerships and open-access initiatives that opened up the benefits of new technology to a wide range of innovators and SMEs. DotEcon's independent assessment shows that the BBC's investment in R&D has delivered a return of between £5-9 for every pound spent.

161. Based on these considerations, we believe that the department is well placed to support the BBC in the 2017-27 Charter period.

162. However, the BBC will face a rapidly changing market and operating environment in this period, with new partnership opportunities in new areas of technology, new competitors, a changing broadcast value chain, and different standards and norms that shape the UK and global media ecosystem.

163. In response R&D must continue to evolve its focus and skills. While much of its current activity will remain relevant, some areas will change; and some entirely new challenges will need to be addressed, both in the interests of audiences and for the wider benefit of industry. R&D will need to continue to flex its partnership models and choice of partners to adapt to a rapidly changing technological and market environment.

164. While it is too early to specify precisely what initiatives will be required over the whole of the Charter period, given the great rate of change in media technologies, our review of the activities currently planned in these areas suggest they represent an appropriate initial response to the strategic challenges faced by the BBC. They will:

a. Deliver for audiences and society, aligned with the BBC's public purposes, giving licence fee payers access to more personal, responsive and shareable experiences, and seeking to bring the benefits of Internet connectivity to all audiences;

b. Give the creative community the tools they need to deliver the public purposes in an Internet- and mobile-first age, for example with the further development of Object-Based Media, working with partners to create content that is 'aware' of the user and user surroundings and can be repurposed across different channels, enabling multiple experiences to be built from a single content asset;

c. Enhance the BBC's cost-effectiveness and value for money, for example by managing the BBC's costs of distribution, driving efficiencies in production and rolling out low-cost automated transcription tools; and

d. Deliver value to industry and the UK, for instance by helping build a new technical ecosystem capable of delivering new types of content, and based on common standards that make these new content types universally available.

165. So in the 2017-27 Charter period, BBC R&D will continue to have a number of vital roles to play. It must help transform the BBC to ensure it fulfils its public purposes in a very different media environment, specifically by preparing it for a smooth transition to Internet delivery, focusing on delivering value for younger audiences, and by placing personalisation, participation and partnership at the core of the BBC's services and operating model. In pursing all these objectives, collaboration with others will continue to be key.