The Great Innovation Challenge

How challenge prizes can kick-start the British economy

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Any errors or omissions are, of course, our own.

About Nesta and Nesta Challenges

Nesta Challenges exists to design and run challenge prizes that help solve pressing problems that lack solutions.

We shine a spotlight where it matters and incentivise people to solve these issues. We are independent supporters of change to help communities thrive and inspire the best-placed, most diverse groups of people around the world to take action. We support the boldest and bravest ideas to become real, and seed long-term change to advance society and build a better future for everyone. We are part of the innovation foundation, Nesta.

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nesta Challenges

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Executive summary

The government's ambitious plans to boost science and innovation are a golden opportunity for bold, game-changing investments.

Challenge prizes are a tried and tested method for incentivising and supporting innovation, and for ensuring that R&D is responsive to the needs and aspirations of our society. While the UK was a pioneer in using challenge prizes, including the Longitude Prize of 1714, it is now the US that leads in their use.

In this paper, we set out how an ambitious programme of challenge prizes could play a vital role in the revitalised UK innovation funding system envisioned in the government's R&D Roadmap.[1]

The paper diagnoses the strengths and weaknesses of the UK innovation ecosystem as it currently stands: well-publicised strengths in basic science, but underperformance in turning that research into economic and social benefit for all. The government's policies to greatly increase funding and create new institutions, including a UK ARPA-style body, are a welcome vote of confidence in British R&D. They need to be paired with action to do things differently: supporting new innovators, leveraging private investment and guaranteeing public benefit.

It sets out principles for what might do this; greater methodological diversity in innovation funding mechanisms, including the wider use of challenge prizes, which Nesta Challenges has been championing since its formation in 2012.

As the details of the new R&D funding are worked out in the forthcoming Spending Review, we believe that these new innovation policies need to unlock human and financial potential that is currently being missed; they need to embrace the risk and uncertainty inherent in setting ambitious goals; they need to focus on topics that capture the public imagination. And they need to be robust and data driven, with rigorous evaluation of new methods and old, so we know public money achieves the biggest possible impact.

The paper explores how prizes are making a comeback – in the UK, the US, Europe and Canada – and explores four case studies of multi-million dollar US technology prizes. These have had unique effects – articulating ambitious and exciting visions of the future, giving credibility to whole new sectors, and demonstrating the benefit of new technologies.

We argue prizes should be a strategic part of the innovation funding mix in the UK, across a wide range of sectors.

And so we tentatively identify seven themes – ranging from space to genomics – that we think have promise – and where we might find the moonshots that a new, ambitious national programme of challenge prizes could tackle.

1

Diagnosis of the current landscape

Britain has strengths to build on, but weaknesses to address.

- **The government's continued commitment to its target for 2.4 per cent of GDP to go to R&D is a welcome vote of confidence in British innovation.**
- **It is an opportunity to do things differently – supporting new innovators, leveraging private investment, channeling money towards public benefit and engaging the public in science and innovation.**
- **Challenge prizes are a tool that offers a distinctive and underused contribution to innovation funding in the UK.**

Britain will be spending more on research and development in future. The Chancellor announced ambitious new spending targets in the March 2020 Budget,[2] reaffirmed by the Prime Minister in June.[3]

Despite the economy being blindsided by COVID-19 and urgent new demands on the public purse coming to the fore, the government recognises this is now not just a priority, but an imperative: the UK R&D Roadmap sets out the government's thinking, and the critical role that innovation will play in rebuilding after the crisis.[4] The next step is the Spending Review, in which the detailed decisions will be made about how this money gets spent.[5]

Whatever happens, public money and private will flow into labs and facilities, funding work on a scale the country has not seen in generations. Public investment in R&D alone will reach £22bn per year by 2024-5, from £9.6bn in 2018.

The prize: tackling Britain's poor productivity; driving lasting prosperity; creating innovations that serve the public good. And rebuilding a more resilient and balanced economy to help us recover from the shock of coronavirus.

And so we support these ambitions.

But the promises of new funding and new urgency, welcome as they are, are only the beginning. We propose this paper as a contribution to the discussion started in the R&D Roadmap – a vision of how a more innovative, experimental and bold approach to allocating funding could help deliver these goals, including through ambitious challenge prizes.

Strengths and weaknesses

Britain has world class strengths in R&D – but it has weaknesses too. Low funding – now being addressed by government. Geographical imbalance.[6] And the way innovation is funded, the impact it has and how well it is evaluated could all be improved too.

Simply scaling up public funding will replicate and amplify our failures as much as it will build on our successes. Meeting the target of 2.4 per cent of GDP being spent on R&D – and doing so without the taxpayer footing the whole bill, without missing open goals, without funding the wrong things, all while maintaining public support – will have to mean doing things differently, as already argued in Nesta's *Innovation after Lockdown* report.[7]

The R&D Roadmap provides a welcome opportunity to think carefully about how this extra government funding is deployed. To build on our strengths – but also to be honest about where we are weak and how we can improve. And to make sure that every additional pound of public money has been carefully targeted to have the biggest possible impact for Britain's economy and society.

As Nesta has argued before,[8] to meet the challenge of making Britain more innovative, we don't just need to spend more, we need to spend differently. New institutions, perhaps, to complement the work of UKRI: here, the proposed UK ARPA-style body could be key. And new funding mechanisms to expand the narrow toolkit of R&D grants and tax credits that make up the lion's share of public R&D funding at present.

In this paper we explore one of these funding mechanisms in particular – the challenge prize. We explore its unique features, track record in the US and UK, and the role we argue it should play in the UK R&D ecosystem.

What's wrong?

Any diagnosis of failings in Britain's R&D ecosystem first has to acknowledge that in one respect, Britain gets things very right.

Research is a jewel in Britain's crown. The UK's universities turn relatively modest public funding into world beating research.

The metrics are imperfect and have many critics, but citations, publications in high-impact journals, successful bids to Horizon 2020, university league tables or the findings of the RAE and REF all tell a similar story of research excellence.[9]

And yet, when it comes to the wider economic benefit that should flow from R&D – creating patents, technologies, products and services that actually get used and have commercial impact – Britain's record is different.

Again, the metrics are imperfect, but tell a consistent story. For the size of our population and our economy, Britain lags behind its peers, with low R&D investment by companies[10] and fewer patents than Germany, France, South Korea or Japan.[11] And the activity which does happen in the UK is more likely to be in foreign-owned companies than in UK-owned firms.[12]

This could be framed as a failure to convert or leverage Britain's strength in research into strength in development – but this interpretation is simplistic. There isn't a neat and linear path from scientific research to its application and commercialisation – the links between basic and applied research are much weaker and messier than that.

But there are also countries that have managed to get the best of both worlds. South Korea and Germany are good at both basic science and its industrial applications – and use their strengths in each to benefit the other; the US has famously built links between industry and academia, with Silicon Valley forming around Stanford University[13] and the Cambridge-Boston biotech cluster around MIT and Harvard.

So it is legitimate to ask why the UK's success at basic research is not matched by similar strengths in its applications.

Part of this is surely down to low applied R&D funding by international standards, where the UK has historically lagged the OECD average, let alone leaders like South Korea, Israel and Japan.[14]

The main programmes that the UK government uses to support applied R&D are effective: existing UK funding is not wasted. Direct financial support (for instance through Innovate UK grants and the high profile Industrial Strategy, as well as programmes like the Small Business Research Initiative) generate additional activity that wouldn't have happened otherwise.[15] R&D tax incentives do too, though at great cost.[16]

With the additional funding promised by the Chancellor, programmes like these could be expanded to support more firms and more projects. But by focusing on just a handful of mechanisms, we miss out on funding organisations and areas of focus that deserve public support, which could quite easily be supported through a more methodologically diverse innovation funding toolkit.

Tax incentives are barely targeted at all. They treat large companies (RDEC) and SMEs (SME R&D relief) differently, and restrict support to technical (as opposed to process or service) innovation, while the patent box scheme specifically supports patented innovations. Aside from this, these schemes do not distinguish between different kinds of innovation and different kinds of company. They provide, in effect, a blanket subsidy to firms. There is merit in the simplicity of an approach like this, but in a time of tight public finances, it is far easier to argue for targeted support for work on topics of public benefit.

R&D grants, such as those administered by Innovate UK, are more targeted and far easier to justify to the public. The Industrial Strategy Challenge Fund programme, for instance, has invited firms to submit proposals related to tightly-defined calls for proposals that align with the government's industrial strategy – which in turn, link to economic and social priorities for the UK.

But grants can't do everything.

Grant applications will often play it safe and promise only what seems achievable; and grant reviewers will often play it safe by only awarding funding to those applications that seem likely to succeed. That means too much support for safe options – this is borne out by such grants rarely failing but also rarely leading to breakthroughs[17] and is recognised in the R&D Roadmap's criticism of bureaucracy and risk-aversion.

Since grants award money up front based on a promise of what work a team will do, not the outcomes the funder wants to achieve, they can end up playing it safe on process too. More innovative approaches are hard to justify, and divergence from the agreed plan is punished rather than rewarded – even when it would mean delivering better on the original objectives of the grant.

Neither grants nor tax incentives have solved one of the defining weaknesses of the UK R&D sector: private companies are simply not investing enough of their own money in innovating.

What's next?

None of these are weaknesses that mean these initiatives should end – rather, they should be complemented with institutions and methods that behave differently.

Institutional reform is already on the agenda. Indeed the institutional landscape has already changed substantially in recent years. The reason challenge prizes are even part of the debate in the UK is down to government investment in creating Nesta Challenges in 2012. On a larger scale, the formation of UKRI and the integration of the research councils, the creation of the Catapult Centres and Scottish Innovation Centres and new research institutions like the Crick and Turing all show a willingness to innovate with the institutional foundations of innovation in the UK.

These all addressed identified weaknesses in the innovation landscape, from lack of coordination and strategic direction to provision of facilities and support.

The promise of an ARPA-style body, with a budget of £800m to spend over five years and a remit to fund high-risk and high-reward projects[18] has been presented as a radical and disruptive addition to this landscape (though as we have seen, innovation is no stranger to institutional change).

Speculation has been rife: how the ARPA-style body will actually operate has been the subject of vigorous debate,[19] and the R&D Roadmap offers promising language around breakthrough technologies, long-term thinking and innovative funding mechanisms.

Done right, alongside the Wellcome Trust's new Leap Fund, it could have the freedom and institutional culture to make some of the bold, big bets that the UK's current institutions and methods mostly do not – and address some of the weaknesses in grant funding by taking more risks, being more flexible and engaging more deeply with outcomes and less with process.[20]

When it comes to innovative methods, the path forward is less well defined.

The Industrial Strategy has provided a coherent narrative and set of missions that take a step towards methodological innovation, but it has been delivered through the usual mechanism of R&D grants.

The Chancellor has hinted at a more heterodox approach to innovation methods, including a reference to 'new funding models' in the budget,[21] and the R&D Roadmap goes some way further to outline these, but there is still plenty to do to articulate exactly what the right innovation funding toolkit looks like.

2

Ideas to shape the future of innovation funding

What principles should guide new institutions and methodologies?

- **New methods and institutions should aim to be distinctive, both in how they operate and how they create impact.**
- **They should be tried out in tandem with robust evaluation – to inform best practice in future.**
- **They should release untapped potential, embrace uncertainty and address challenges that matter.**

New institutions and methods bring with them an opportunity to shape and fine-tune the outcomes that we aim to achieve.

Reforms in the methods and institutions that deliver innovation funding in the UK should be accompanied by robust experimentation and data gathering, to better understand whether the money we spend is achieving the impacts it should – and to inform future policy over which innovation funding mechanisms work best to achieve different goals.

What principles could guide us in this?

Release untapped potential

There are talented innovators who are just waiting for an opportunity, and there is money just waiting to be invested. New methods and institutions should seek to exploit this potential.

That means channelling opportunities to unusual suspects – smaller companies, more radical ideas, innovators from non-traditional backgrounds – giving them a chance to shine. And designing programmes thoughtfully so that they crowd in as much private investment as possible for as little taxpayer's money as is feasible.

Embrace uncertainty

Rather than playing it safe, new institutions and mechanisms should be smart about risk and reward. That doesn't mean being reckless, but it should mean giving innovators licence to try more radical, less orthodox approaches, or to pivot and change direction. Courage from government can generate courage in innovators.

Linking some or all funding to outcomes, rather than inputs; and supporting multiple innovators rather than making single, big bets, can mitigate the risks to public money while still giving innovators the space to truly innovate.

Address challenges that matter

Finally, since we are talking about increases in public money – and what's more, at a time when the economy is faltering and household budgets are under pressure – new institutions and methods need legitimacy. Not all innovation is of public benefit, and it is not good enough just to point to the economic payoff – one which voters will only benefit from indirectly, if at all. There can't just be financial support for strategic industries – there needs to be public support too.

And so, new institutions and methods need to capture the public imagination, to be driven by ambitious missions, informed by foresight and future methods, to set innovators the task of solving challenges that make life in the UK better. This is consistent both with the R&D Roadmap and with Nesta's previous research on public attitudes to innovation.[22]

3

A historic idea that's made a comeback

From navigating the seas to navigating the skies, challenge prizes can create breakthrough innovations.

- **Challenge prizes support innovators through incentives instead of subsidy.**
- **They are radically open, both to new ideas and to new innovators.**
- **In the past 15 years, governments and foundations have rediscovered this approach to innovation funding.**

We believe that one of the new methods that should be far more widely used, which would help UK innovation funding achieve these principles, is the challenge prize.

Challenge prizes turn the R&D grant model on its head. Where grants offer a subsidy to the team that seems best placed to solve a problem, challenge prizes offer a reward to whoever first or most effectively solves them.

This tweak – moving from an up-front subsidy to an incentive that pays out later based on success – makes a profound difference. Because they do not rely on deciding up-front which proposal is best, reserving judgement until there are real results, they are far more open.

Open to different innovators: plucky upstarts who have the skills but don't have the track record or the privilege to beat the incumbent players in a grant application, but who could outsmart them if they were given a chance.

Open to different ideas: unusual approaches, new technologies or unconventional methods that diverge from the received wisdom of how to solve the problem.

Open to a different way of doing R&D: which accepts that the original plan might not work, and gives innovators space to rethink and restart, because all that matters is what you deliver at the end.

Prizes were once widespread as a way of pushing technological frontiers. Britain pioneered their approach – most notably with the Longitude Prize, solved by a Yorkshire clockmaker, John Harrison. But there were literally thousands more, many run by the Royal Society of Arts, over many decades.[23] A last big hurrah for prizes was their widespread use in the early 20th century to push the boundaries of aviation – with the first crossings of the English Channel and Atlantic, among other firsts, happening thanks to teams competing in the Daily Mail prizes.

But then, they went out of fashion.

The age of prizes rewarding the plucky underdog, of ingenuity winning out, was over.

Instead, big research grants flowed to worthy research institutes – reflecting, yes, the scale and complexity of the problems facing developed economies, and how many of them need vast teams and huge resources… but perhaps in there, too, a wish to play it safe.

And yet, in the past 15 years or so, prizes have been creeping back into the mainstream. Starting with the Ansari X Prize, awarded in 2004 for the first private spacecraft to send a human above Earth's atmosphere, governments and foundations have gradually rediscovered how open competition can sometimes be the best solution.

Where there's a clear goal, but it is not clear who is best placed to reach it or which approach is best; and where the gold and the glory might attract new attention and speed up problem solving, prizes have found their niche.

The US government is a big user, through the Challenge.gov platform, that has run around 1,000 prizes since 2010;[24] the European Commission has also put up tens of millions of euros in prizes to solve problems ranging from cleaner diesel engines to cheaper space launchers as part of its Horizon 2020 programme.[25]

And the UK has joined in too, including a £10m prize on saving antibiotics, launched to celebrate the 300th anniversary of the Longitude Prize in 2014.

But in the UK, adoption has been case-by-case, led by individual government departments in search of a tool to solve a specific problem – rather than deployed strategically as part of the government's technical and economic development toolkit.

Perhaps the most impressive commitment to this funding model is in Canada, where challenge prizes are now a core part of innovation funding. The Impact Canada initiative, which Nesta Challenges is an adviser on, has committed over C$700m to challenge prizes and other similar outcomes-based funding mechanisms since the Trudeau government came to office (and has invested in robust evaluation to track their impact).

Challenge prizes are well suited to tough problems where the market is not delivering solutions.

They work best when they meet some common sense criteria:[26]

- You can define a clear goal, backed up by unambiguous criteria – so innovators know what they are being asked to do.
- There is a clear benefit from fresh thinking and new innovators – for instance a field that is stagnant or has too few players in it.
- New innovators could be effectively incentivised to take part – because the financial reward is sufficiently attractive and the barriers to participation sufficiently low.
- The funding and support will accelerate progress – rather than just fund activity that was already going to happen.
- There is a path to financial sustainability for the successful teams – so that the winners do not disappear once the prize money runs out.

4

Challenge prizes in practice

Lessons from across the Atlantic show how large prizes are a unique and distinctive method.

- **Challenge prizes create breakthrough innovations: they articulate a clear vision of the future, and when deployed by governments this can help direct innovation and create new industries.**
- **They help innovators thrive: participating in a prize provides credentials and visibility to innovators, particularly unusual suspects.**
- **Public demonstrations and judging help validate and promote the new technologies developed, kickstarting their entry into the market – and starting the process of systemic change.**

Challenge prizes in their modern incarnation have now been around long enough that there are lessons emerging about how and where they work best.

In particular, we can look to some of the larger prizes that have been launched in the past two decades in the US where their use came earlier and where many of the biggest prizes have been run.

Overall, this track record endorses the proposal that challenge prizes should play a significant and systematic role in the innovation funding mix.

These American prizes illustrate strengths in the method that would be hard to replicate using other innovation funding mechanisms.

Their focus on a tightly-defined problem means they create a clear, shared mission by the competing teams and develop a shared vision of the future. They also have a low barrier to entry, with typically many teams competing – including long-shots and unusual suspects. Together, these create momentum around creating breakthrough innovations that solve the problem.

The profile-building, testing and validation of innovations that are inherent to a prize help innovators thrive. Challenge prizes are naturally high-profile affairs, with teams competing to win; determining who those winners are requires expert judging and robust independent testing. Together, these improve innovators' game, provide them with independent validation and raise their profile. And although prizes are competitions, where teams are vying for position against each other, they also build shared purpose and collaboration. Cohorts of successful teams focusing on the same problem help create networks and momentum around a topic.

Beyond the innovations they help unleash, and the innovators they support, prizes also bring about broader, more systemic change. This can be industry or sector building and awareness raising, through the high profile of the prize; developing innovation alongside regulation or policy; or building momentum around investment and new funding. Prizes can help identify best practice, shift regulation and drive policy change. The public demonstration of technologies that occurs in prizes is a key contributor to this.

A thread running through almost all of this is the role challenge prizes can play in legitimising an issue: the signal sent by a funder that the problem is important, that working on it is a serious endeavour and that the future can be different.

Looking in more detail at some of these high-profile and large-scale US prizes can illustrate the diverse ways in which these unique characteristics manifest themselves.

The Ansari X Prize

Creating breakthrough innovations

The Ansari X Prize was created in 1996 to demonstrate that privately-financed space flight was viable, and had commercial potential.

Teams competing for what became a $10 million prize would have to launch and return a reusable manned spacecraft 100km into space twice within two weeks. 26 teams from seven countries built rockets in attempts to win the prize, each funded entirely by the team.

The prize was won from a launch site in the California desert in October 2004, on the anniversary of the Sputnik launch. The Mojave Aerospace Ventures team was led by aerospace designer Burt Rutan and his company Scaled Composites. It was financed by Microsoft co-founder Paul Allen.

On its first flight, their SpaceShipOne left the carrier plane and rolled 30 times on the way to its target height, but it made it over 100km and was judged successful.[27] The next week, thanks to some engineering tweaks to stop the rolling, pilot Brian Binnie reached 112km. He returned to earth with a new world record for the height reached by an aviation vehicle and $10 million for his team.

Helping innovators thrive

Brian Binnie's experience on the edge of space was lauded as the beginning of space tourism.

X Prize Foundation chairman and founder Peter Diamandis said that President Bush phoned the winning team to offer his congratulations: 'He said that it was great to see the spirit of enterprise alive in America and opening up the space frontier.'[28]

Diamandis was clear from the beginning that the aim of the prize was to show that it is no longer just governments that could go to space.

He had read about the Orteig Prize, a $25,000 reward offered in 1919 by New York hotel owner Raymond Orteig for the first non-stop flight from New York City to Paris. This prize, along with earlier aviation prizes sponsored by the *Daily Mail*, was crucial to the development of today's $300 billion commercial aviation industry.

Diamandis wanted to prove that private industry can build a viable vehicle for sending paying passengers to space, kickstarting the space tourism industry like the aviation prize a century before.

The teams were motivated by the same goals. 'It is a thrill that I think everybody should have once in a lifetime,' pilot Brian Binnie said at the time.[29] Indeed, it is speculated that Paul Allen paid more than $20 million for SpaceShipOne, twice the prize money. X Prize Foundation says that over $100 million was spent on research into suborbital flight between the 26 competing teams.[30] The prize must have offered more than just a financial incentive.

The winning technology was licensed by Richard Branson a week before the final flight. Branson hoped five successors to SpaceShipOne, each with a five-person capacity, would enter service by 2008. Today Virgin Galactic is going strong, but has been dogged by delays and a serious crash in 2014. The company still has hundreds of customers signed up to take their seats on the first commercial flights, which are hoped for in 2020.

Another team, Blue Origin, backed by Amazon founder Jeff Bezos is also expected to fly people to suborbital space this year. SpaceX and Space Adventures have partnered up to fly private citizens to orbit aboard the SpaceX Crew Dragon spacecraft next year. Northern Sky Research estimates that the global suborbital and orbital tourism market could generate $14 billion in revenue by 2028.[31]

The challenge prize used the extensive media coverage that it generated to legitimise the industry and to raise the profile of the innovators who took part. This profile-raising is in part an inherent feature of a competition, but it was also something explicitly sought out in the Ansari X Prize's design – with multiple flights generating multiple opportunities for media coverage.

The Ansari X Prize also influenced regulation to benefit the teams – during the preparations for attempts to win the prize, Peter Diamandis realised that the launch and landing could not legally happen in the USA based on regulation at the time. The foundation had to lobby the Federal Aviation Administration to change the rules to allow private suborbital flight tests to take place within the United States.

The X Prize Foundation is now a well-established vehicle for technology-driven incentive prizes in different industries and at different scales, but at the time of the Ansari X Prize it was not. It was born from Peter Diamandis' personal frustration with the government-driven space industry. He did not understand why there was a stigma attached to private space flight development. After announcing the $10 million prize, he says he went to over 100 funders without success. So he took out an insurance policy that would pay out if he did not find a funder, even that cost $2.5 million which he paid back over time. Eventually, in May 2004, the Ansari family offered to pay off the policy and sponsor the prize. Leveraging himself and his fundraising skills was a risk Diamandis took as the only way he could see to make progress in the industry he had always dreamt of being part of.

Today, he argues that prizes work best as a way to support innovation in a domain which has been constrained by this kind of stigma.[32]

The DARPA Grand Challenges

Creating breakthrough innovations

The US Defense Advanced Research Projects Agency's (DARPA) Grand Challenge for autonomous ground vehicles was launched in 2002,[33] a year after receiving a Congressional mandate to make one-third of the military's ground vehicles unmanned by 2015.[34]

They designed a course with professional off-road drivers, that was set up in the Mojave Desert in the United States – the same area that the Ansari X Prize winner would lift off from. This 229km route remained under wraps until the competition day in 2004.

On that day, DARPA promised $1 million for the fastest vehicle to finish the course within a 10 hour window. A few hours before the race began, DARPA gave the teams a file with a series of 2,500 GPS waypoints that they had to pass to complete the course. This was the first information they had about the course so their vehicles had no chance of learning it in advance, but had to navigate it autonomously. Teams were only allowed to use GPS to monitor their vehicles. The only direct control was a kill switch controlled by DARPA, to be used if one of the vehicles endangered a human.

None of the seven teams that qualified for this race completed more than 5 per cent of the circuit. In 2005, DARPA tried again, offering a $2 million prize for the fastest vehicle to finish a new 212km course, which now also included stunt drivers in other vehicles as well as static obstacles, to make the environment more realistic. This time, 5 out of 23 teams completed, with Stanley, Stanford University's modified Volkswagen, winning. Carnegie Mellon, who came furthest in 2004, were beaten into second place by the machine learning system Sebastian Thrun had designed for Stanley.

In 2007, DARPA moved away from the desert terrain roots of the prize and announced a $2 million prize with a second-place $1 million prize for completing a 60km route in an abandoned urban environment. Other robotic vehicles would be on the road, and the entrants had to navigate complex decisions like 4-way crossings. Out of 20 spots in the final, Carnegie Mellon triumphed this time, with six vehicles – each associated with a different US university – completing the course.

Helping innovators thrive

The teams brave enough to enter the event in 2004 had some spectacular failures, illustrating exactly how immature the automated vehicle industry was.

Dr Tony Tether picked out a few highlights from the first event in a 2017 interview: '[Now ex-Google and Uber self-driving engineer Antony] Levandowski's two-wheeler, he got so excited, he forgot to throw the switch for the stabilization and it fell right over… Another little car went up a berm and flipped over. Another had a GPS problem — it tried to go through a barbed wire fence and got tangled up.'[35]

The team that got the furthest in 2004 were Carnegie Mellon University's Red Team, led by William 'Red' Whittaker who already produced small autonomous robots. The team were doing test runs on similar terrain a month before the event. Like almost all of the competitors, they use a combination of laser pulses sent out like radar (LiDAR) and video cameras to sense the environment around the vehicle. The key technical challenge they overcame was a software one: knitting this information together as a decision-making algorithm for the car. Chris Urmson, their software lead, created a new system for this before he had even finished his PhD.

LiDAR has since developed into an important part of the self-driving industry, as well as for sea and aerial navigation. After entering the 2004 challenge, David Hall saw that the use of LiDAR could be greatly improved by a 360 degree revolving detection system rather than two static sensors. Taking his previous subwoofer and speaker business in a new direction, he developed a new perception detection system sold as a steering input to five of the six teams that finished the 2007 race. Velodyne Lidar today serves 50 customers, including the biggest firms involved in self-driving cars. In 2016, Velodyne announced $150 million in investment from Ford and Baidu, valuing the firm at about $2 billion.[36]

But it is the story of Sebastian Thrun that neatly summarises the industry's meteoric rise. In July 2003, the roboticist left Carnegie Mellon for Stanford. He was a spectator at the first race, leaving with an idea for how to drastically improve the performance of the vehicles. He decided to use the now common techniques of machine learning to set up a vehicle that learnt from its environment rather than one programmed to respond to set challenges. He trained Stanley by programming the car to learn from its mistakes rather than teaching it what to do. This led to Stanford's win over Thrun's previous colleagues at Carnegie Mellon in 2005, despite Carnegie's dominance up to that point.

In 2009, Thrun was hired by Google to build a self-driving car that people could use on the roads. Thrun called Urmson, previously of the Carnegie Mellon team and offered him the position of chief technical officer of the project. He also hired Antony Levandowski and other engineering talent from the challenges. In 2018, the team produced Waymo One, the first fully self-driving vehicle taxi service, in Arizona. Today, Waymo is conservatively valued at $30 billion, with over $2 billion of external investment in the latest round.[37]

Thrun is forthright about how much this shook up the robotics and automotive industries: 'None of what is happening in self-driving today would have happened without the original challenge – it created a new community. They were all newcomers, and the innovation doesn't come from the core of the field itself but from the outside. The experts are usually the lowest performers, because they're totally bound in their way of thinking. Very few self-driving car people knew anything about machine learning at the time, for example.'[38]

As much as amateur teams played a role in the early challenge prize, once the vehicles started to make progress, corporate sponsorship and tie-ins began to be formalised. Automobile companies provided parts and often vehicles for free. Google, Intel and Red Bull logos covered some of the vehicles. Austin Robot Technology was made up of people from IBM, AMD, Sun Microsystems and the University of Texas. These relationships formed the basis of what went on to become new companies or research teams.

The US Department of Energy's Wave Energy Prize

Create breakthrough innovations

Launched in 2015, this 'design-build-test' competition offered money for building prototypes for wave energy converters, testing at the US's most advanced wave-making facility and then prizes of $2.25 million split between the top three competitors.[39] This prize competition came after a decade of growth in incentive prizes, and was designed with lessons learnt from the early X Prizes and DARPA challenges. It also had a less ambitious industry-creating objective: the Department of Energy wanted to create an even playing field for the emerging pre-commercial and diverse technologies, creating more technically and economically viable solutions.

The aim, as in other prizes, remained to encourage participants from outside the existing engineering community using a potential large cash payout as incentive. There was also recognition that more diverse teams can enter if prototypes were also funded by the prize provider; and that free testing could help technologies reach the stage where investors show interest.

Ninety-two teams registered for the prize, with 11 reaching the final, second round of prototype testing in early 2016. The finalists received up to $125,000 in seed funding to build scaled prototypes at 1/20th of the size of a product they would ultimately operate.

Four of the finalists met the Department of Energy's goal of doubling the cost efficiency of energy captured from ocean waves relative to current large scale test sites around the US.

The most successful was AquaHarmonics, which comprised two engineers based in Oregon.[40] They won the $1.5 million first prize with a device that attaches a floating buoy to the seabed, collecting energy from the changing distance between buoy and seafloor caused by waves. Alex Hagmuller and Max Ginsburg, who made up this team, had started building wave energy technology in their spare time about five years before the prize. They were engineering graduates, but not part of a large company or institution, and would have likely not succeeded in their continued development of their product without the prize.

Second place, and $500,000, was awarded to a team that came from a lab at Berkeley. Marcus Lehmann and his company CalWave Power Technologies also had an anchored wave energy technology. He was a graduate student of Mohammad-Reza Alam's lab, who worked on technologies inspired by the way that mud is moved onshore from the seabed by strong waves during the Indian monsoon.[41] They used the movement of sediment as a model for how their device would move, with a set-up that looks like an underwater 'wobbly bridge'. This kind of design was exciting for the judges because it is less likely to be damaged by the waves on the surface unlike many of the wave energy companies already active on other continents.

One of the reasons behind CalWave Power Technologies' success is that it offers a novel technology that could help the US leapfrog the strong, and already at scale, solutions coming out of Europe.

The Berkeley lab behind the company has continued to test different versions of an artificial seafloor carpet. As this kind of product does not need to reach the ocean surface, it is particularly suitable for deep or rough seas. It will be more resilient to storms and can therefore be positioned further away from calm coastal water relative to other solutions. Given that the most consistent and most valued wave energy comes from the swell of the ocean rather than wind close to the shore,[42] this kind of technology has more promise long term.

Help innovators thrive

These top teams, as well as others in the competition, benefitted from the testing at the cutting edge US naval facility in a way that might not be obvious. International standards for measuring wave energy technologies had just started to be put together in 2016. It was hard to get investment or international interest without a demonstration that your kit met these standards. So the in-depth testing provided to the finalists for free was part of demonstrating their legitimate place in this globally emerging sector.

The winners, AquaHarmonics, said that in 2015 their progress had reached a standstill and that they needed costly tests and verification to make progress: co-founder Alex Hagmuller said that in this respect 'it was like [the] Wave Energy Prize was made for us.'[43]

The Department of Energy published data from all the finalist teams' test results to help support their legitimacy and progress against international standards. They also finalised plans for a new national ocean testing facility for wave energy converters in Oregon, based on the evidence that expensive pre-commercial testing was a barrier for many firms. The centre, known as PacWave is now open.[44]

The US Department of Energy has continued to provide significant grants for research to firms involved in the prize. The largest of these were bigger than the original prize pot. Less than a year after the prize, AquaHarmonics was funded to build a bigger version of its energy-converter concept and test it in the ocean.[45] The next step is testing a 1/7th scale version of the device at a large ocean test site connected to the electricity grid in Hawaii.[46]

CalWave Power Technologies also benefited from the same round of funding. It also received two rounds of Department of Energy research funding in 2019, which primarily went to university research teams. The total funding from these rounds is not disclosed, but is likely to be close to $5 million in total – ten times the prize money CalWave originally received.

KidneyX and the Redesigning Dialysis Prize

Creating breakthrough innovations

The US Department of Health and Human Services, the American Society of Nephrology and the National Kidney Foundation have completed Phase 1 of their Redesigning Dialysis Prize. They are looking for solutions that help kidney patients with alternatives to dialysis as it is practised today.[47]

They have awarded fifteen finalists from the first stage $75,000 each for their designs. These designs had to replicate normal kidney functions and improve patient quality of life. The solutions improve treatment in a numbers of ways from improving patient mobility to better engineering to avoid risks like blood clotting.[48]

Phase 2 challenges participants to build and test prototype solutions, or components of solutions, that can replicate normal kidney functions or improve dialysis access. The most successful three prototypes in Phase 2, which could include entrants who did not take part in Phase 1, will each receive $500,000.

The emphasis on understanding patients' needs is part of the design of this prize; it is about re-orientating effort to support those on dialysis rather than looking for alternatives like growing organs from scratch, which might be decades away from widespread use. More than 100,000 patients in the United States each year start either temporary or permanent dialysis. Last year there were just over 21,000 donor organs available for transplant.[49] There will be many people who live for a long time relying on a dialysis machine. With this in mind there is a fund for patients to design their own solutions alongside the main prize, offering small grants up to $2,000. There is also a requirement for entrants to the main prize to engage with patient groups.

The federal government in December 2019 allocated $5 million in public funds for KidneyX. Given the $35 billion spent annually in the US on dialysis, this prize has an economic motivation as well.[50] There will be more follow-on prizes under the umbrella of KidneyX after the current phase two is over.

Entrants into this prize were given a detailed roadmap for the goals of the project and the kinds of solutions that the sponsors are interested in. But unlike the DARPA or Ansari prizes, this was not a technical specification for how to win the prize. It focused more on explaining why, for them, better renal care means new forms of dialysis, wearable devices, implantable devices or steps towards regenerated kidneys. They want to move the community away from incremental changes to current machinery, which has become the norm thanks to low funding for kidney medicine. But they also wanted to avoid too much focus on technologies that are decades away like synthetic organs.

One of the first round winners, a team led by Shuvo Roy from UC San Francisco ultimately wants to produce an implantable biomechanical kidney.[51] But the prize led them to design a small home dialysis unit based on their preliminary designs for the implantable one. The focus on improving quality of life now rather than waiting for a full solution helped redirect their attention.

Help innovators thrive

The required patient engagement for all entries comes with introductions to patient groups that have already signed-up to support the prize: 'We know that many KidneyX applicants will be entering the kidney space for the first time and will not have direct access to patients. As such, we have developed a list of contacts at reliable partner patient organizations that could help identify patients that would be interested in providing direct feedback to KidneyX applicants.'[52]

This appears to have changed the narrative for some of the entries, with demonstrable awareness of improving quality of life in the winners of phase one, including the UC San Francisco team above.

The Department of Health and Human Services divisions participating in KidneyX include the Centers for Medicare and Medicaid Services, the Food and Drug Administration and the National Institutes of Health . This combination offers new access to – and a sympathetic ear from – large patient populations, regulators and research funders.

KidneyX preceded, and perhaps helped make the argument for the Executive Order signed by President Trump in 2019 to launch Advancing American Kidney Health. The initiative provides specific solutions to deliver on three goals: fewer patients developing kidney failure, fewer Americans receiving dialysis in dialysis centres, and more kidneys available for transplant. In particular, it is pushing for regulatory change to make home dialysis possible for more patients – led by the regulators who will need to make that change.[53]

The winners of Phase 1 of this competition have received an additional $75,000 to support their prototypes for Phase 2. Moreover, they now each have confirmation that their idea is viable from the panel of 40 experts that judged that round, as well as online videos showcasing their work from the US Government. This should help support their case for additional investment. One company, Outset Medical, recently closed a round of $125m funding for its solution. It was established in 2003, so some of its technology and reputation predates the prize. But the win in Phase 1 is central to its promotional information, and with the momentum of the additional government funding for KidneyX, will likely have helped it secure that funding.

Lessons from the US experience with prizes

These four case studies demonstrate how prizes have been used in different industries, by different funders and with different objectives.

But they also have some clear common characteristics, which set them apart from what might have been achieved through other methods.

All four created a clear vision – and transformed that into a legitimate pursuit. The Ansari X Prize proposed that private ventures could access space. The DARPA Grand Challenges created a new industry around driverless cars. The Wave Energy Prize created a bold vision of renewable energy. KidneyX is galvanising action around a clearly articulated problem. The prizes all set out a strong signal that their funder was taking the problem seriously and galvanised action around it. The high profile of these challenges prizes was essential to this success.

All four provided credibility to a successful community of participants – and gave legitimacy to them as innovators. The Ansari X Prize helped generate $10 in outside investment for every dollar in prize money, a clear statement of confidence. The DARPA Grand Challenge gave visibility and opportunities to demonstrate to small and non-commercial teams. The Wave Energy Prize funded validation and testing of the competing technologies. And KidneyX helped connect innovators with regulators and patients to build their capacity. The broad cohort of teams guided through a challenge prize was essential to this success.

Finally, all four used demonstrations as a way of building credibility around the problem and the innovators – but also around starting to shift systems. This varied from regulatory change in the case of the Ansari X Prize, to experimenting with autonomy in urban settings for the DARPA Grand Challenges, contributing to a broader policy goal around kidney health for KidneyX and creating a domestic technology base in wave energy for the Wave Energy Prize.

The open demonstration, judging and awarding of challenge prizes – and the publicity surrounding them – were essential to this success.

5

It's time prizes became mainstream in the UK

Britain has taken important first steps, but we could do much more.

- **The government has already funded prizes such as the Longitude Prize for antimicrobial resistance.**
- **The lessons from UK and US prizes could shape a programme of ambitious, industry-creating prizes.**
- **The UK has built expertise in Nesta Challenges on how to design prizes large and small, which stands ready to help deliver these.**

In the UK, by the early 2010s, the emerging track record in the United States, and the 300th anniversary of the original Longitude Prize, there was growing interest in government in the unique contribution that challenge prizes can make.

In 2007-9, Nesta, then still part of government, had piloted the Big Green Challenge, a challenge prize for community initiatives to cut CO_2 emissions. And in 2012, Nesta and the Department for Business, Innovation and Skills (now Business, Energy and Industrial Strategy) agreed to create the Centre for Challenge Prizes – now Nesta Challenges.

The Centre for Challenge Prizes was explicitly created with an aim to run prizes, but also to develop UK expertise and capacity around them.

Since then, it has run around 40 prizes, large and small, and advised on many more, in the UK, Europe (through designing many of the Horizon 2020 prizes) and internationally, most notably in helping establish the Impact Canada initiative.

This has generated further useful learning around large prizes like the US examples in this paper.

Nesta Challenges' multi-million pound challenge prizes include the 2014 Longitude Prize (on antimicrobial resistance), the Mobility Unlimited Challenge (on mobility aids for people with paralysis) and the Open Up Challenge (on fintech solutions that help small businesses). These demonstrate many of the strengths outlined in the previous section.

Nesta Challenges has also run many smaller prizes, and has expanded the understanding of challenge prizes as a method – for instance in how they can be used as a tool to drive scaling (the Million Cool Roofs Challenge), as method of regulatory experimentation (the Legal Access Challenge) or fostering early-stage startups (the Inventor Prize). In the Longitude Explorer Prize, we even have a challenge prize focused specifically on bringing young people into tech entrepreneurship.

We believe that the track record of prizes in the UK and US shows the potential they have, demonstrates that they would address clear weaknesses in the UK innovation funding ecosystem and would make a positive contribution to the country.

A future programme of strategically focused UK technology challenge prizes needs to learn from the evidence laid out in this paper.

It also needs to contribute to knowledge about what works. There is less evidence around innovation funding than there should be – on what methods work best, and in what circumstances. There are good reasons to believe that challenge prizes work, just as there are with R&D grants and tax credits, but as the Chancellor of the Duchy of Lancaster recently pointed out, evaluation should be at the heart of government policy making.[54] The funding of innovation should be no exception – and a large, strategic programme of challenge prizes is an excellent opportunity to generate evidence and test what works best.

Based on this – and on some of the economic, policy and social priorities facing the UK in coming years – we can begin to sketch out what some of these prizes might look like.

6

A vision for British technology prizes

What kinds of industry could the UK stimulate with a programme of challenge prizes?

- **Prizes that could help kick-start whole industries.**
- **Prizes that could build on Britain's record in deep technology.**
- **Prizes that could send an optimistic message of leveraging technology for public benefit.**

Prizes can be part of an ambitious programme to create new tech-driven industries in the UK.

The groundwork has already been laid. Ambitious new funding levels mean we can dream bigger dreams than before. The Industrial Strategy has created the precedent for government intervention, driving forward missions in strategically important areas. The creation of UKRI and the the plans for an ARPA-style body match those ambitions with new institutions.

What role for prizes then?

Three characteristics of the successful, industry-defining US prizes discussed in this paper show what ambitious prizes could do here.

A national programme of prizes in the UK should, like those US prizes, seek to articulate a clear vision and convert this into a legitimate pursuit, provide credentials to a successful community of participants and demonstrate the value of the technology and innovators being developed.

But we don't want to send tourists into space – that was Diamandis' personal goal – nor should we focus on military vehicles – that's DARPA's game.

Instead, we are looking for industries where the UK already has strong foundations, where we could provide a critical testbed and signal Britain's ambitions to the world.

This suggests a focus on deep tech where our world leading research base is superbly placed and a global challenge, where the UK will be supporting others but also have a first-mover advantage in new infrastructure or services.

Given public money is at stake, there should be clear public benefit: a focus on sectors that deliver environmental protection, human wellbeing and reduced inequality.

As an illustration of what a national programme of challenge prizes could look like, we offer these seven examples of sectors where we think the potential is strong.

Smart green shipping

A century ago British ports were at the heart of our heavy industrial economy – importing and exporting machinery, coal and raw materials. Half a century ago, shipping was transformed by containerisation.

Now, a data-powered revolution is sweeping the sector – making shipping smarter and greener: better serving today's complex supply chains while meeting climate change targets. It could help make supply chains more resilient too, a key concern exposed by the coronavirus pandemic.

This is a clear growth area – ShipTech is already worth $100bn today and is forecast by Inmarsat to grow almost threefold by 2030.[55, 56] Meanwhile, SMEs' role in this market is growing fast, but from a low base of just 4 per cent of the technology market, and there is a clear opportunity for British firms to capture a share of this.[57]

Britain has already taken steps in this industry, through the DfT's Maritime 2050 strategy and its commitment to innovation in the sector. And funding has followed with the creation of the Maritime Autonomy Regulation Lab (MARLab) and a Clean Maritime Innovation funding call.[58]

A challenge prize on smart green shipping could provide a UK port as a testbed – and invite the UK's innovative SMEs to test out solutions for more efficient handling and routing of freight – rewarding the innovation that is most effective at cutting costs and carbon emissions.

Articulating a clear vision

☑ Transforming a polluting, legacy industry into a clean, tech and data-driven sector.

Providing credentials

☑ Supporting innovative SMEs to break into an industry that is currently dominated by big players.

Demonstrating the value of the innovations

☑ The prize will showcase innovations and raise their profile.

Strong UK foundations

☑ Britain is a historic maritime nation, has an efficient ports sector and a strong ecosystem of tech entrepreneurs.

Possible testbed

☑ A UK port or ports could be used as a testing and demonstration facility.

Deep tech

☑ Advanced data science and AI will be at the heart of the innovations.

Global challenge

☑ Shipping and logistics are a globalised industry with huge export potential.

Public benefit

☑ Clear link to public benefit through reduced carbon emissions and improved air quality.

Living maps

The Ordnance Survey is a national asset with centuries of experience in mapping. It is also an innovator – behind its maps are vast amounts of constantly-updated geospatial data.

Mapping and its uses have evolved with the digital revolution. For consumers, technologies from Google Maps to Uber rely on accurate geospatial data to provide services that we all use. For businesses, everything from advertising to the space sector are voracious users of geospatial data.

And new technologies such as drones and satellite constellations create new opportunities, with cheaper, richer and more regularly updated data. Maps are no longer static – they are alive.

The government has seized the opportunity too. The Public Sector Geospatial Agreement has widened access to Ordnance Survey data to innovators; meanwhile 2018 saw the creation of the Geospatial Commission to maximise the opportunity that location data provides for society, economy and the environment.

At the same time, though, we have seen signs of how this technology can be misapplied – with growing privacy concerns around smartphone locations and unaccountable businesses tracking their customers.

A prize on living maps would ask innovators to reinvent maps for the 21st century: the challenge would be to create a new service that solves a defined challenge facing a particular community. Innovators would have to combine public sector geospatial data with the latest technology and service design, to create new, ethical tools that create public benefit, and demonstrate adoption among the target audience.

Articulating a clear vision

☑ Leveraging geospatial data for public good and showing that it can be used in a way which respects privacy.

Providing credentials

☑ Providing access to public-sector geospatial data will demonstrate that the teams are credible players.

Demonstrating the value of the innovations

☑ The prize will reward innovations that demonstrate that they have been adopted in their target audience.

Strong UK foundations

☑ Britain has world-leading geospatial data (through the Ordnance Survey), strong government support and a thriving ecosystem of tech and satellite data firms.

Possible testbed

☑ The prize could focus on a particular city or region, or provide a specific dataset for the innovators to experiment with.

Deep tech

☑ Data science is at the heart of living maps, the UK's space and drone sectors are also highly relevant.

Global challenge

☑ Geospatial data is important around the world and a crucial enabler of high-growth sectors.

Public benefit

☑ Clear link to public benefit through the target of the prize and the focus on privacy.

New materials for clean air

Although pea soupers are a thing of the past, dirty air is not. Thanks to connected networks of sensors, we now have a better and more detailed understanding than ever before of where air is polluted, and how badly. King's College London and its London Air Quality Network[59] is Europe's most comprehensive air quality monitoring network.

Improving data capabilities, and cutting emissions – from cars, industry, heating – will be key to reducing health impacts. Both are priorities in the Industrial Strategy.

But there are also innovative ideas for how the built environment itself can be used to clean up the air – through materials that capture pollutants. A European Commission challenge prize on developing such materials was awarded in 2018 so there is a precedent for a prize in this sector.[60]

British companies and universities have highly relevant expertise – from the data science and measurements that pinpoint where pollution is, to the chemistry and materials science involved in neutralising it. These could both be leveraged to advance the technology, reduce cost and create robust evidence of effectiveness.

The prize would focus on developing and testing these materials at scale: the prize should be run with a local council or combined authority as a real-world testbed for the innovators to work in, and extensive, robust testing would be part of the programme. The winning teams would be decided based on how effectively and at what price their technology reduced the levels of key pollutants (such as nitrogen oxides and particulate matter) in the air around their test locations.

Articulating a clear vision

☑ Practical technologies for cleaning up the air we all breathe.

Providing credentials

☑ Demonstrating support from government and local authorities.

Demonstrating the value of the innovations

☑ The prize will see pilots of the technologies tried out in real environments where they can demonstrate the benefits they bring.

Strong UK foundations

☑ Britain has world-leading materials and data science, both in universities and in the private sector.

Possible testbed

☑ The prize would focus on a particular region, and would incorporate extensive technical testing.

Deep tech

☑ Molecular modelling and materials science would be key to solving the challenge.

Global challenge

☑ Large export potential, particularly to polluted cities in the Global South.

Public benefit

☑ Clear environmental and health benefits to the public.

Carbon sequestration

Britain's legally binding climate change emissions targets mean we must urgently decarbonise power generation and industry.

Renewables are a key part of this roadmap. But capturing and burying the carbon dioxide produced when fossil fuels are burnt could be a complementary approach.

The 2020 budget promised £800m for carbon capture and storage, and a promise to establish the technology at two sites by 2030,[61] building on millions of pounds already spent by government on research in this field.[62]

These plans are for large-scale capture of carbon dioxide at the site of large-scale emission (industrial sites and power stations).

But other approaches for capturing emissions or sucking CO2 from the atmosphere, for example through ocean or soil management, can also be part of the solution, as witnessed by a number of recent research grants.[63] These are potentially more flexible, varied and resilient approaches, which aren't tied to the location where the pollution is produced, and which can be solved by many different technical approaches, from materials science to nature-based solutions.[64] It's not just a technical challenge – one key problem is the lack of a clear business model.

This prize would incentivise the development and testing of scalable and affordable approaches to carbon sequestration – with a particular emphasis on radical innovation. The winning team would be the one that demonstrates the greatest ability to remove carbon dioxide from the atmosphere at a given cost. Teams would have access to testing facilities, such as the new University of Sheffield centre, opening in 2021.[65] Such a prize would particularly benefit from being run alongside regulatory change that helped establish a market for the solutions that are created.

Articulating a clear vision

☑ Radical and innovative approaches to removing carbon dioxide pollution from the environment.

Providing credentials

☑ Giving visibility and support to a wider range of more innovative approaches to the problem than are currently being favoured.

Demonstrating the value of the innovations

☑ The prize will test and validate the technologies.

Strong UK foundations

☑ The UK government is already funding substantial work in this area – this prize would broaden the range of innovators receiving it.

Possible testbed

☑ UK facilities, such as at the University of Sheffield, are already being set up under existing policy.

Deep tech

☑ This could incentivise work across a range of deep tech fields from materials to biotech.

Global challenge

☑ Climate change is the greatest challenge we face.

Public benefit

☑ Huge public interest in reaching net zero carbon emissions.

Microbiome-based therapies

The microbial communities that exist within our bodies have profound impacts on our health. Thanks to research such as that carried out by the EMBL-EBI Metagenomics Lab in Cambridgeshire, we are starting to gain a data-driven understanding of the complex microbiome that is in and around us.

The human microbiome is implicated in a large number of medical disorders, from Parkinson's to colon cancer, as well as metabolic conditions such as obesity and type 2 diabetes. But interventions to manipulate the microbiome are crude: probiotic and prebiotic diets and fecal transplants.

But there are promising signs. Labs such as Wellcome Sanger are carrying out academic research, EMBL-EBI is partnering to develop industrial applications of its data and private companies are carrying out research too – such as Bristol spin-out Ferryx, which is developing treatments for gastrointestinal inflammatory illness.[66]

A prize in microbiome-based therapies would reward the team that develops a proven, safe and effective microbiome-based therapy. As part of lowering the bar to entry and ensuring innovative SMEs can thrive, participation in the prize could include access to key datasets and support with testing. The prize would pair well with government intervention to make the UK a more attractive location for clinical testing.

Articulating a clear vision

☑ Creating a new industry in the UK around an area of high potential.

Providing credentials

☑ A vote of confidence in an exciting but currently early-stage area of medical research.

Demonstrating the value of the innovations

☑ The prize will test and validate the therapies.

Strong UK foundations

☑ The UK has phenomenal strength in drug discovery and biosciences, and has strong institutions such as Wellcome Sanger.

Possible testbed

☑ Especially if the prize can be paired with government support for clinical testing.

Deep tech

☑ High tech challenge, leveraging biosciences and data science.

Global challenge

☑ Human and animal health are universal issues.

Public benefit

☑ Addressing health and wellbeing for all.

Personalised therapies

Precision medicine is a new approach to healthcare in which patients are diagnosed and treated according to their individual needs. By tailoring treatment to a person's genetic, phenotypic, social or environmental attributes, we can improve the effectiveness of treatment and reduce toxicity.

Precision medicine is in a period of breakout growth thanks to advances in some fundamental technologies, including digital health records, routine genome sequencing and new complex drugs (often tailored to an individual).

Despite all this promise, there are enormous economic, regulatory, behavioural and ethical challenges to the introduction of personalised medicine. One key barrier is the expense, time and difficulty of bringing new treatments to market – particularly in relation to the small market for drugs tailored to ever smaller sub-groups of patients.

Nevertheless, the field of personalised medicine should deliver enormous returns because the techniques used to develop new treatments are often based on biological approaches that, once perfected, can be adapted to a wide number of individual diseases. Similarly, while these drugs are often extremely expensive, they can also save money through avoiding years of treatment costs to the NHS and years of ill health for patients.

A challenge prize in precision medicine could focus on promising areas, where there is a high unmet need for a small number of patients who are currently unlikely to receive investment from pharmaceutical companies, and where there is a class of drugs that is suited to very rapid clinical development. The prize should be delivered in partnership with the health system – with support for testing and trialling from UK hospitals and regulators – and with access to high-quality data that allows teams to make a rapid start with analysis and interpretation.

Articulating a clear vision

☑ Providing the technology to support a revolution in medicine, helping people with rare diseases and unmet clinical need.

Providing credentials

☑ Providing strategic support to new innovators in a sector where the UK has historic strength.

Demonstrating the value of the innovations

☑ The prize concept is focused on technologies and methodologies that are critical enablers for therapeutic development.

Strong UK foundations

☑ The UK has phenomenal academic and business strength in pharmaceuticals and advanced therapies.

Possible testbed

☑ Especially if the prize can be paired with government support for infrastructure, such as the National Genome Research Library, Catapults and Medicines Manufacturing Innovation Centre.

Deep tech

☑ High tech challenge, leveraging biosciences and data science.

Global challenge

☑ Human and animal health are universal issues. Other emerging economies may benefit and also provide examples of frugal innovation.

Public benefit

☑ Supporting access to medicines for people with rare conditions and expensive or hard to treat conditions.

UK access to space

The UK is a leader in commercial uses of space, but the sector is at a tipping point with opportunities to do so much more. Pragmatic government decisions and a strong engineering base mean the UK has specialised in relatively lucrative parts of the value chain: space enabled services (including Inmarsat and Sky Television) and in satellite manufacture, including smallsats.

Today, the need for space enabled services is growing ever faster, from satellite broadband to deliver connectivity everywhere, to earth observation data that can be combined with AI to help us manage our planet in ways needed for the 21st century.

But British success in space has frequently been foreign-owned and large parts of the value chain, including launchers and spaceports, have historically not been a focus. Decline in demand for satellite TV, along with positive disruptions including microlaunchers, miniaturisation, mega-constellations and in-space robotics and manufacture mean that the shape of the sector is changing.

The UK has the opportunity to realise an ambitious, space enabled future and has been creating the policy environment and signalling the intent to do so.

The UK announced last year the creation of the National Space Council, has promised strategic investment in British spaceports, and has taken a golden stake in OneWeb which will position the UK to be a leader in advanced satellite technology and services. The Industrial Strategy Challenge Fund is investing £99m for RALspace to create the National Satellite Test Facility. Previous strategic government investments include the creation of the UK Space Agency and the Satellite Applications Catapult.

A challenge prize to support innovation in the UK space sector could focus on an eye-catching and ambitious technological or service breakthrough – such as developing technology to remove failed satellites from orbit, creating a robotic platform for in-orbit servicing of satellites, or a staging post in low earth orbit to enable large scale manufacture or return products developed in microgravity to earth and maximise the benefits possible from UK launch. Innovators participating in the prize could be given access to launch sites, testing facilities and given support navigating the complex regulation of the industry. Structuring the prize around key technical milestones such as launches and test flights would help build profile and awareness.

Articulating a clear vision

☑ Creating breakthrough technology and world firsts in spacecraft design.

Providing credentials

☑ Providing a seal of approval to UK SMEs that helps them gain private investment.

Demonstrating the value of the innovations

☑ Technology demonstrators, launches and test flights would be a key part of assessing the prize.

Strong UK foundations

☑ Strong SME base and policy support.

Possible testbed

☑ Particularly if paired with access to UK national facilities and spaceports.

Deep tech

☑ High tech precision engineering challenge.

Global challenge

☑ Fast-growing global demand for satellite services.

Public benefit

☑ Space-based services key for rural connectivity, disaster response and environmental planning.

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