COUNCIL FOR SCIENCE AND TECHNOLOGY

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Prime Minister
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Dear Prime Minister

Robotics, automation and artificial intelligence (RAAI)

The increasing convergence of robotics, automation and artificial intelligence will generate significant new market opportunities and transformative applications. By taking appropriate steps now, the UK could build upon its existing strengths to stand at the forefront of these developments, and reap substantial economic and societal benefits from existing and emerging markets.

RAAI is, in our view, an important element of industrial strategy, and a key ingredient for achieving your vision of an economy that works for all. It can underpin the creation of new businesses in new industries that will shape our future lives.

We attach a note which explores the opportunities and recommends three actions concerning challenge areas, facilities and skills.

Work on this topic has been led from within the Council for Science and Technology by Professor Philip Bond (University of Bristol), supported by Professor Sir Keith Burnett (Vice Chancellor, University of Sheffield), Professor Steven Cowley (CEO, UK Atomic Energy Authority), Professor Fiona Murray (MIT Sloan School of Management) and Colin Smith (Group President, Rolls-Royce).

We would be pleased to discuss our recommendations with you or your ministerial colleagues.

We are copying this letter to Philip Hammond, Greg Clark, Jo Johnson, Ben Gummer and Jeremy Heywood.

Mark Walport

Sir Mark Walport
Co-Chair

Nancy Rothwell

Professor Dame Nancy Rothwell
Co-Chair

1. The subject of this letter is the diverse field arising from the combination of robotics, automation and artificial intelligence (hereafter RAAI). RAAI systems are interconnected, interactive, cognitive and physical tools, able to variously perceive their environments, reason about events, make or revise plans and control their own actions. RAAI embraces technology areas such as sensors, actuators, control systems and advanced batteries – and disciplines including systems engineering, metrology and computer science. The interaction of these various areas and disciplines signals a new phase for RAAI, and its potential to deliver greatly enhanced and far-reaching applications. The UK is well placed to facilitate these interactions, where much will depend on harnessing the potential of artificial intelligence, and is already focusing on opportunities around connected and autonomous vehicles and aerial drones. As costs continue to fall and further gains are made in accuracy, reactivity, decision-making, analytical power and autonomy as a whole, more new markets will emerge.

2. RAAI's most significant impact to date has arguably been in manufacturing, but the next wave will involve a broader range of applications in additional sectors, thanks in large part to gains in autonomy. Physical robots, web robots and other systems will increasingly possess the ability to undertake a wider array of actions, even in the face of unexpected events and unfamiliar environments.

3. The UK has missed the opportunity to play a significant role in designing or deploying industrial robots. However, it has the necessary expertise to play a major role in the next wave of developments in RAAI – provided it focuses on key challenges, invests in translational facilities and strengthens its skills pipeline. Our three recommendations (paragraphs 15 to 26), address each of these issues in turn.

4. The UK possesses domestic strengths in a breadth of disciplines, with pockets of excellence in robotics and autonomous systems as well as a range of underpinning areas: software, artificial intelligence (AI), sensing technologies, design and engineering. In particular, the UK is a world leader in software and AI – with outstanding research at a number of major universities and getting underway at the newly formed Alan Turing Institute.

5. A number of countries, including China, Japan, South Korea, Germany and the US, are intent on exploiting next-generation RAAI and establishing market leadership; they are investing accordingly. If the UK wants to capitalise, it needs to take decisive action now. It needs to be a leading player in both the disciplines and technologies which comprise RAAI and in achieving their interaction.

6. In the broadest terms, there is much to be gained from exploiting and extending our current strengths in RAAI. With one recent report estimating that these technologies will have an impact on global markets of up to $4.5 trillion per annum by 2025, the creation and expansion of innovative RAAI-related businesses would boost growth, generating and protecting jobs in the UK.

7. National productivity stands to benefit considerably from adoption of RAAI. For the period 1993 to 2007 alone, researchers have concluded that the average contribution of robots in manufacturing to annual labour productivity growth and GDP across 17 countries – despite their limited penetration in some – is on a par with that of steam technology to British annual labour productivity growth in the 19th century. Other reports suggest a modest increase in the use of *existing* technologies among UK manufacturers would yield a substantial leap in productivity. Allied to this, RAAI would also drive improvements in the quality of goods and services that would not be possible by other means.

8. The same is true of public services. RAAI has clear potential to address challenges in areas such as health and social care, energy security and nuclear decommissioning, and remove humans from other hazardous environments. These are both domestic as well as international priorities, meaning export opportunities for those countries who are first to identify scalable market solutions.

9. For all these reasons, RAAI should be a fundamental ingredient of industrial policy: as a field of multidisciplinary research where the UK has clear strengths, a set of enabling technologies, and given its centrality to both existing and emerging sectors. There are obstacles, however, to the UK leveraging its current assets and to assuming a leading international position. Despite the breadth of capability in our research base, we do not have strength in depth nor the critical mass necessary to cater to increased future demand for RAAI.

10. Innovative firms lack information about potential returns on investment from RAAI. They lack easy access to advanced facilities and equipment where they can test RAAI in real-world settings and explore its potential in collaboration with others. They require advice on how best to invest in unfamiliar technologies. The research base and business, meanwhile, need to improve their mutual understanding of industrial priorities and technology readiness levels in order to achieve more fruitful interaction. We note the efforts of the UK RAS Network, representing academia, and the RAS Special Interest Group, from the industry side, to improve dialogue and coordination. These efforts should be built on – but they are not sufficient, in isolation, to capture greater value from RAAI in the UK. Government has a role to play in building on this momentum.

11. Equally, there are serious consequences associated with not developing UK strengths in RAAI and with not accelerating its adoption domestically. Failure to keep pace with global take up of next-generation applications could see the UK trailing its global competitors. This applies not just to productivity, where the UK already compares poorly internationally for robot density per worker, but to delivering quality in high-value markets where the UK could excel.

12. We are aware that government has been exploring the impact of RAAI on jobs through its “future of work” agenda. It is important to tackle this issue head on. Even if RAAI is analogous to previous disruptive technologies – where job creation resulting from the positive effects of longer-term productivity gains

ultimately surpasses short-term job losses – jobs displacement is still likely to occur in the interim. This risk will need to be managed by government. Concerted efforts will be needed, for example, to upskill and reskill displaced UK workers. At the same time, the UK will only protect and create jobs in the long term by strategically investing in RAAI. If it fails to invest, it will be unable to compete with countries who will be both more productive and able to deliver higher quality, thereby putting more jobs at risk.

13. We were struck by the lack of robust evidence about the social and economic impacts of RAAI, including on displacement in the labour market. Government could address this problem by commissioning its own research. This might also be a useful complement to the ongoing review of productivity data were it to consider how to measure and account for the true impacts of RAAI on productivity. Given the pace at which RAAI is evolving and becoming disruptive, however, a clear policy will be required before definitive evidence can likely be gathered.

14. We acknowledge the value of existing activities on RAAI, especially the 2014 RAS 2020 Strategy and subsequent roadmap, the leadership of the UK RAS Network and the RAS Special Interest Group, and EPSRC's and Innovate UK's support for underpinning research, technologies and translation. We also recognise the attention it is currently receiving within government, as well as from the Commons Science and Technology Committee. The priority now is to build on these activities in a coordinated way. The three recommendations set out below have been conceived in that spirit.

Recommendation 1: Identify challenge areas of economic opportunity and national significance for the UK to improve focus and encourage collaboration

15. Government, together with the RAAI business and academic communities, should define multidisciplinary challenge areas around which the UK should focus its efforts and seek to deepen capabilities. A similar recommendation was made in the RAS Strategy.

16. The challenge areas for RAAI should meet the following criteria:
    - they embrace research fields in which the UK has excellent capability and the potential to become (or remain) world leaders
    - they offer large productivity and quality gains in high-value global markets (current or emerging) – enabling the UK to attract inward investment and capture long-term value
    - they offer the prospect of applying solutions to other priority challenge areas for the UK and global markets.

17. The challenges should be run along the lines of the US Defence Advanced Research Projects Agency (DARPA) programme, albeit with a more civilian focus – a cross-cutting "X-ARPA". DARPA challenges have several key features: effective problem definition; outstanding programme management; demanding timescales; openness to a wide range of entrants, including

SMEs; a culture which encourages collaboration and creativity, but also accepts the possibility of failure; and arrangements for participants to access high-quality equipment and facilities. The UK has experience of its own in challenge setting in both military and civil contexts. We should exploit this experience, noting that another ingredient of successful challenges is their ability to spark the public imagination.

18. This challenge approach should have two additional objectives: to share expertise between military and civil activity in UK RAAI, and exploit Government procurement systems to drive innovation and adopt resulting solutions.

19. From our investigations into RAAI, two broad challenge areas were brought to our attention with particular promise in terms of meeting the criteria above: health and social care (including robotic surgery, independent living and working, and patient care) and hazardous environments (including nuclear, and underwater exploration and infrastructure maintenance for the oil and gas sector). These should be explored further, as part of a thorough assessment of potential challenge areas.

Recommendation 2: Expand UK demonstrator and translational facilities for RAAI to de-risk commercial investment, provide business and technical advice, cross-fertilise ideas and coordinate activity

20. Government should address demand for facilities where companies can access RAAI equipment, test and see applications in action, rent space and interact with other businesses, and source advice on market entry. These facilities should seek to provide a coherent package of support across the relevant technology readiness levels to aid translation.

21. Any new or repurposed facilities should deliver two other critical functions. The first is providing access to the engineering and systems integration expertise necessary to advance the technology-readiness levels of concepts emerging from the research base and create scalable products and services. The second is providing a coordinating role to harness the UK's geographically dispersed strengths within RAAI, as well as the wider research base, in order to encourage spill overs to new application areas (in line with the objectives of the newly created body, UK Research and Innovation).

22. It is worth investigating whether a new facility or facilities could operate in the applied technology domain of the Catapult network – whose approach can embrace the challenge function outlined in recommendation 1 – alongside other potential options. It should complement and draw upon existing institutions and facilities, including the Alan Turing Institute, other technology areas covered by the Catapult network (such as the digital and high value manufacturing components) and the autonomous vehicles test beds.

Recommendation 3: Develop UK advanced skills and research capability in RAAI to build critical mass in the science base, the wider translational system and in industry

23. The first two recommendations would boost the development and retention of RAAI talent in the UK. However, we recognise the need to focus efforts specifically on producing more people with advanced skills to broaden and sustain research excellence in advanced robotics technologies and to deploy RAAI technologies in industry.

24. To address both, we recommend scaling up EPSRC's successful doctoral training programme, whose centres already boast high levels of support from industry and for which demand for places outstrips supply by as much as 10 to one in its centres.

25. During our inquiries, we were struck by the importance of systems engineers in making the necessary linkages among the different RAAI disciplines to address real-world problems. Many companies complained about the apparent lack of systems engineers, although we lack evidence to corroborate this. We propose that Government investigates the state of the advanced skills pipeline for RAAI, including for systems engineering, to ascertain current and future demand.

26. We also propose that more consideration be given to international collaboration: to harness insights from overseas, to ensure that domestic capabilities remain at the leading edge and to bolster critical mass within areas of UK strength.